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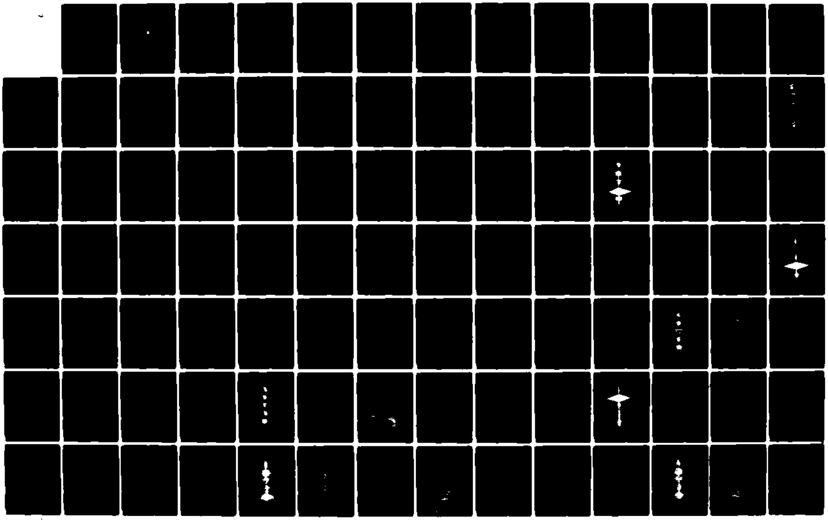

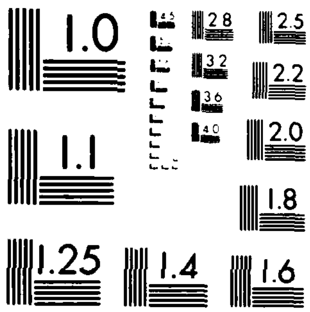

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Monterey, California

THESIS

MULTIPLE TARGET IDENTIFICATION
AND DIRECTION FINDING
USING MATCHED FILTERING TECHNIQUES

by

James L. Johnston

December 1983

Thesis Advisor: H. A. Titus

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Multiple Target Identification and Direction Finding Using Matched Filtering Techniques

by

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Submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN ELECTRICAL ENGINEERING

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This research investigates seismic signal processing techniques for battlefield target classification and acquisition. Multiple target classification is performed by discrete time domain matched filtering. Multiple target directions are determined using the responses of the matched filters and least mean squares polynomial curve fitting. The least mean squares polynomial curve fitting procedure is also used for direction finding for recoil/blast sources, using the unfiltered seismic signals.

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I. INTRODUCTION

Timely and accurate combat intelligence is a integral part of the modern battlefield. A primary goal of combat intelligence is target acquisition. Hostile targets can be acquired by either passive or active means. An example of passive target acquisition is visual target identification. Radar, on the other hand, is an active target acquisition device. An effective combat intelligence system will include a mix of both active and passive target acquisition methods.

Rapidly advancing technology in the fields of electronic counter-measures and radiation-seeking weapons has enhanced interest in passive target acquisition methods. To be cost effective, as an additional target acquisition system, a passive system must be able to provide swift and accurate target identification, location and tracking information on hostile targets. A variety of seismic sensor systems have been used in this roll with varying degrees of sucess.

Naval Ocean System Command (NOSC) in San Diego has developed a system based on a circular ring of sensors with data collection managed by an array-processor/minicomputer system [Ref. 1]. The observation of enemy movements and activity beyond the Forward Edge of the Battle Area (FEBA) is the design objective of this system. This thesis uses data collected during a test of this system at the Marine Corps Air-Ground Combat Center at Twenty-nine Palms, Califiornia. Investigated are various methods of processing the seismic data collected. The objective of this research is to try to provide viable methods of satisfying system design objectives through signal processing techniques.

The following chapter addresses the design objectives and requirements for such a seismic sensor system. Additionally, capabilities and deficiencies of current systems and research are detailed. In order to intelligently address solutions to these requirements and deficiencies, an understanding of seismic theory and sensors is needed. General seismic theory is presented with emphasis on the constraining parameters for the use of the earth's surface as a medium for gathering seismic intelligence. Also highlighted are the similarities of the earth's surface to electro/optical phenomena and the resulting simplifying assumptions.

The sequence of design solutions investigated followed from the analogies and simplifying assumptions addressed in the study of seismic sensor theory. The problem of target identification or classification is approached using digital matched filtering of the time domain amplitude data. Frequency domain matched filtering was not considered, based upon the conclusion by NOSC that there appeared to be no consistent spectral lines for any of the possible target types, except for artillery [Ref. 1]. Matched filtering was used to identify single and multiple target classes occuring during a sample period. The chapter detailing the matched filter procedures and implementation also includes a description of support and validiation software used in the analysis of the seismic data.

The validation software is primarily used to check the accuracy of the direction finding routines. These direction finding routines are the time domain phase difference procedure (TDPD) and a least mean squares polynomial (LMSP) curve fitting procedure. The combining of the matched filtering procedure and these direction routines allowed for multiple target direction finding. The theory and derivations of the two direction finding algorithms are presented in the multiple target direction chapter.

Application of these algorithms is performed first on simulated targets for validation of the procedures. The experimental data is then analyzed. A user's manual, which includes procedures for tape and mass storage operations, is provided as an appendix. This appendix describes how to set up and use the software system.

II. THEORY OF SEISMIC SENSORS

Elastic waves result from the stressing of an elastic media. The elastic media for seismic theory is the earth. Seismic theory is the study of the earth as a wave propagating media. Elastic waves propagate away from the source of seismic stress, e.g. an explosion [Ref. 2]. The energy, which propagates through the earth, travels via particle deformations. The elastic properties and densities of the earth media determine the velocities of these seismic waves. [Ref. 3]. Seismic wave sources of interest may be impulsive or continuous. Impulsive or short duration sources are artillery recoil or shell blasts. The time-limited nature of this type of seismic signal produces a broad range of frequencies. Continuous wave signals may be produced by tanks, trucks and low flying aircraft. These continuous wave signals may be described by narrow band frequency characteristics. The spectral power of a seismic source is a function of several parameters. A non-inclusive list of these parameters includes:

1. The vehicle's velocity and mass
2. The size of the explosive charge associated with the artillery or shell blast
3. The degree of coupling into the earth's surface
4. The geological structure over the wave's path

Information about the seismic source is contained in the waves which it generates. For example, in an array of seismic sensors, directional information is contained in the relative received signal phases. In otherwords, the relative phase differences between the signals received by the individual array elements can be used to compute the direction to the seismic source [Ref. 4]. These relative phase

differences represent the time delays of the waves as they pass the array's elements. The response of the array's elements is proportional to the amplitude and velocity of the earth's motion, relative to the geophone's sensing axis for the waves. [Ref. 3]

Assumptions about the propagation of seismic waves must be made to assist with their analysis. The earth is assumed to be made up of horizontal, homogeneous, and isotropic layers of material. These layers are assumed to be discontinuous in their elastic properties at their borders. This variance in the elasticity between the layers leads to an optical analogy for the wave propagation. Propagation paths may now be viewed as being direct, refracted, or reflected versions of the source's seismic waves. [Ref. 3]

There are four basic types of seismic waves. These types are compressional, shear, Love, and Rayleigh waves. Compressional waves are generated by impulsive sources such as shell blasts. Particle motion is along the direction of travel. Shear waves are characterized by particle motion orthogonal to the direction of motion. The Love wave is a surface wave which may occur as a result of the layering of the earth's surface. This layering effect acts as a wave guide for this type of wave. Particle motion is orthogonal to the direction of wave propagation. The Rayleigh wave is generally the strongest of the seismic waves. The Rayleigh wave travels along the free surface of the earth. Its particle motion direction is always in the vertical direction. It is the strongest wave generated by a compressional source. Its amplitude attenuates at a rate only inversly proportional to the square root of the distance. [Ref. 3]

The waves of primary interest for a seismic system are the Rayleigh and Love waves. This is due to the long-range propagation of these waves. Since these two wave types are orthogonal to each other, they must be sensed by different

geophones. Rayleigh waves may be sensed by vertical geophones and the Love waves by horizontal geophones. Since the Rayleigh wave is normally the strongest, and in order to reduce computational complexity, only verticle sensor data is used.

Rayleigh waves experience absorbtion losses, particularly at higher frequencies. This phenomenon occurs because of the lowpass filter effect of the earth. This filtering effect is further compounded due to the fact that the cutoff frequency of the earth diminishes with range. Further complications arise due to the dependence of wave velocity on frequency. The result being that the wave train may change with distance, reducing the correlation of the wave shape between its source and distant points. Other sources of error occur because of the weathering of the surface layer, irregularities in the sub-surface composition, variances in the earth's layers and surface geometry. [Ref. 3]

III. DEVELOPMENTAL REQUIREMENTS AND PROBLEM DEFINITION

A. PASSIVE TARGET ACQUISITION AND SURVEILLANCE

A battlefield commander possesses a definte requirement for real time combat intelligence. A significant tactical advantage is held by the commander who is able to integrate his availiable combat intelligence sources with his supporting arms, i.e., target acquisition and engagement. It follows that to be part of the target acquisition process, any real time, seismic sensing system must provide swift and accurate information on detected enemy targets. The specific requirements for such a system are the ability to detect, identify, and locate these targets [Ref. 5]. Additionally, the target's rate and direction of movement should be provided or made easily discernible.

Any seismic sensing system must be designed around the target acquisistion cycle. The target acquisition cycle, as given by Dublin [Ref. 5], is as follows:

1. Search Time
2. Target Sensing
3. Information Processing
4. Display of Target Information
5. Analysis of Target Information
6. Time required to make a Decision
7. Time Required for Supporting Weapons to Respond

For a seismic system, a prioritized list of possible targets are as follows:

1. Artillery
2. Helicopters and Aircraft
3. Tracked and Wheeled Vehicles
4. Personnel

As may be expected, the relative amplitudes of these seismic targets vary widely. A seismic targeting system is therefore constrained as to the targets it can or can not be expected to effectively engage.

The variance in the relative amplitudes of seismic targets suggests a range of specifications for detection of these targets. As summarized by Dublin [Ref. 5], possible detection radii may be as shown in Table I. Radii are given for both short and long targeting systems.

TABLE I

Target Detection Radii

Target	Short Range System	Long Range System
Personnel	100M	None
Vehicles	1KM	10-20KM
Low Flying Aircraft	1KM	10-20KM
Hostile Weapons	1KM	15-20KM

The timeliness requirement is ancillary to the radii of detection specifications. Timeliness, as used here, refers to the total time commencing when the seismic sensor system first detects and processes the seismic target data and ending with the dissemination of the targeting information to command elements for disposition. This timeliness requirement ranges between five to fifteen minutes, depending upon the mobility of the target [Ref. 5].

The parameters having a direct effect on the timeliness of a system are the probabilities of false alarm and detection. These parameters directly relate to a system's value. Increased probability of detection with reasonable false alarm performance, combined with the ability to disreguard

friendly targets, are practical design objectives for any targeting system. The ability to incorporate such design features into a seismic sensor system will reduce both the time wasted on invalid targets and the danger of undetected targets.

Once a valid target has been detected, target location information must be obtained. Stringent specifications for target locations allow for the system to support or enhance the effectiveness of; fire support systems, blind bombing, Harassing and Interdiction fire (H and I), and observerless artillery engagement.

B. CURRENT CAPABILITIES AND DEFICIENCIES

To date, numerous successful algorithms have been developed to determine direction to single targets. These algorithms include both time and frequency domain methods. Target identification of long range targets via seismic sensing has not yet met with equal success.

The modern battlefield is seldom a single target type environment. The complicated, real world problems of multiple target identification and multiple target engagement require solution before practical seismic sensor systems can be integrated into the target acquisition process.

IV. MATCHED FILTER CONCEPT AND DISCRETE ALGORITHM

A. MATCHED FILTER THEORY

As previously addressed, there exists a requirement for battlefield target identification/classification. The recovery and classification of target signals suggests a filtering requirement. Previous works and implementations have used frequency domain techniques [Ref. 4]. The Air Force's SKEET system and the U.S Army's Remote Battlefield Surveillance System (REMBASS) both have successfully implemented a spectral power approach for classification of seismic data. These systems, however, are for short range applications. Time domain approaches to target identification have been for the most part left unexplored.

The discrete matched filtering technique is an attempt to classify targets by their time domain amplitude pattern i.e., their seismic amplitude signature. The heuristic basis for this method evolved from the observation of visual differences between the amplitude versus time signals for the various classes of targets. The matched filter, being the optimum filter for detecting known signals, was selected [Ref. 6].

The discrete matched filter is described by equation 4.1, where $h(t)$ is the impulse response of a filter whose output signal to noise ratio at time t_0 is maximized. The unit step $u(t)$ has been added to assure causality for the system. The matched filter is [Ref. 7].

$$h(t) = s(t_0 - t)u(t) \tag{4.1}$$

The output signal is given by

$$\text{sout} = \int_{-\infty}^{\infty} h(v)\,s(t - v)\,dv \qquad (4.2)$$

The maximum signal to noise ratio is given by

$$(\text{sout}^2/M^2)\text{maxoutput} = E(t_o)/N_o \qquad (4.3)$$

Where M is the noise level at the filter output, N is the input noise level, and $E(t_o)$ is the energy in s(t) up to time t_o. In equation 4.2, the replica of the original known signal is reversed and translated in time to be convolved with the signal input to the filter, producing the optimum output signal to noise ratio.

For discrete realization of the matched filter as implemented, equation 4.2 becomes equation 4.4, where h(k) is the reflected and translated known signal.

$$\text{sout}(j) = \sum_{k=1}^{N} h(k)\,s(j - k) \qquad (4.4)$$

Where N is the number of data points per sample period.

B. MATCHED FILTER ALGORITHM

Samples of known signals are stored in a data file and read into a 5120 array at the start of program execution. Five sample, or known filter signals, are recorded in this array. Each sample signal comprises 1024 of the 5120

elements of the matched filter array. To perform the matched filtering, the 1024 seismic data samples (unknown signal) are copied over five times on an array of 11264 size. These copies of the experimental data are separated by 1024 zeros on either side. Additionally, the leading and trailing elements of the experimental data are set to zero to eliminate switching spikes present in the data. Hence forth, this 11264 element array will be referred to as the working array for brevity. This working array will contain the results of the matched filtering. For M, given as the number of input signal and filter signal array elements and also the number of zeros, the requirement set forth in [Ref. 8] for nonoverlapping convolution of length L is satisfied. Equation 4.5 establishes the minimum length for nonoverlapping convolution of one matched filter segment.

$$L = 2M - 1 \tag{4.5}$$

Figure 4.1 depicts the working array layout. Notice that the first filter signal, "Tracked Vehicle" is loaded into the h(t) array and is convoluted with the working array elements one through 2048. Once the leading data point of h(t) reaches the working array's element 2048, a new known signal is loaded into h(t), "Wheeled Vehicle", and the convolution is continued for working array elements 2048 to 4096. This process continues until the last of the five h(t) filter signals has been read in and the convolution has been performed on all copies of the data. Notice that working data array elements 10240 to 11264 are for array length over-run protection.

Prior to convolution, each filter sample signal and the input signal are equalized to the same power level through

```
|ZEROS|DATA |ZEROS|DATA |ZEROS|DATA |ZEROS|DATA |ZEROS|DATA |ZEROS|
|     |     |     |     |     |     |     |     |     |     |     |
    1024  2048  3072  4096  5120  6144  7168  8192  9216  10240  11264
|TRACKED    |WHEELED    |SHELL      |HELO       |PERSONNEL  |
|VEHICLE    |VEHICLE    |BLAST      |           |           |
*           *           *           *           *

* - Indicates point at which new known sample signal
    is loaded into h(t).
```

Figure 4.1 Working Array Configuration

division by their respective root mean square values. Additionally, after the convolution, the entire working array is normalized with respect to its maximum amplitude element. The maximum value in each target classification section is then compared with the interactively selected matched filter threshold. If the section's peak value is above the threshold value, that class of target is declared to be present. This method allows for the simultaneous detection and classificaton of multiple targets. It should be noted that this equalization forces both high and low amplitude signals to an equivalent average power level. This is felt to be justified in that signal amplification is not the goal, rather target detection and classification is. In the case of a single target, the known signal that most closely matches the unknown signal is anticipated to have the greatest amplitude matched filter spike. Figure 4.2 is a sample output.

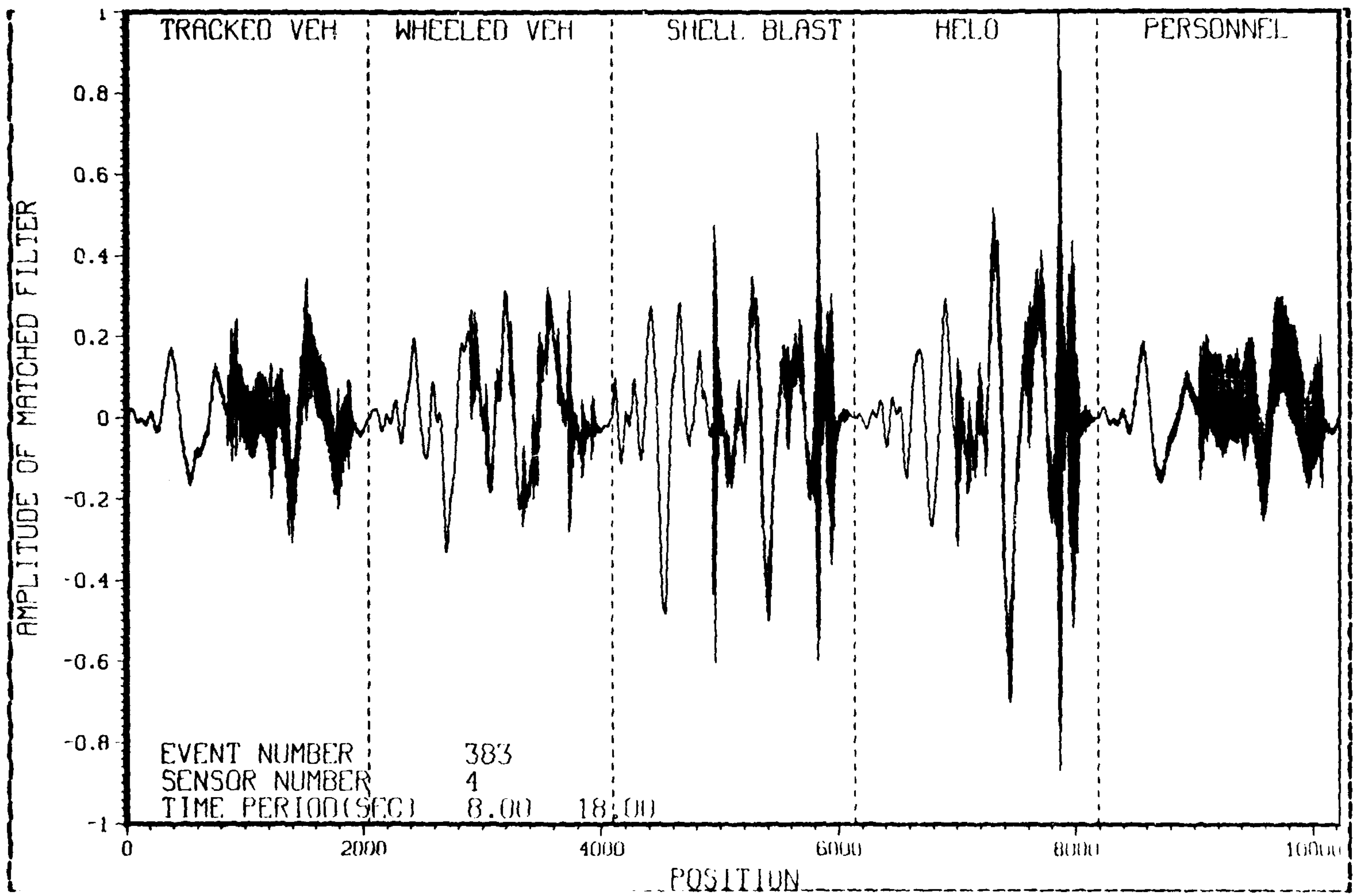

Figure 4.2 Sample Matched Filter Output

C. MULTIPLE TARGET MATCHED FILTERING

The upper limit of equation 4.4 may be selected to be from one to 1024 when called by the multiple target direction routine. This allows for the selection of reduced program execution times. Target identification, however, is always made by the full 1024 element buffer. When the matched filter target identification routine is used by the multiple target direction finding routine, data windows of less than 1024 are formed from a segment of the 1024 elements by extracting the segment size required around the maximum signal value. Figure 4.3 illustrates this procedure.

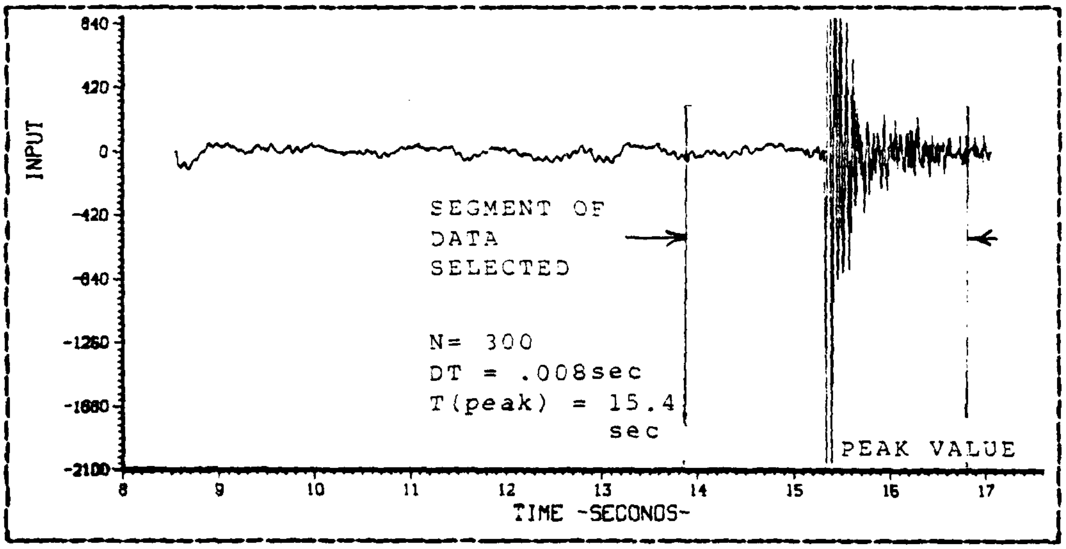

Figure 4.3 Windowing of Experimental Data

D. COMPUTATIONAL REQUIREMENTS

The computational requirements for this procedure are described by equation 4.6, where NO is the total number of operations required by the matched filter routine.

$$NO = (Ndf^2)(Nc) + (Ndf - 1)(Ndf)(Nc) \qquad (4.6)$$

Ndf is the number of data elements and also the number of filter elements. Nc is the total number of target classes. The term Ndf^2Nc is the total number of multiplications required, while (Ndf - 1)NdfNc is the total number of additions.

When used for target identification, Ndf equals 1024 and Nc equals five. Equation 4.6 gives a total of 10,480,640 operations for these array sizes. When the matched filter routine is initiated by the multiple target direction routine, the value of Ndf can be selected to range from one to 1024. Figure 4.4 is a plot of equation 4.6 and shows the computational consequence for selection of large values for Ndf. Note that equation 4.6 must be multipled by the number of sensors in the ring when computing the number of operations for the multiple direction routine.

Window sizes of 100 and 200 were found to provide acceptable accuracy with greatly reduced computation times. As shown by figure 4.4, a window size of 200 requires 399,000 operations, while a window size of 100 requires only 99,500 operations. The number of operations required was found, as expected, to be proportional to the execution time of this routine.

E. SUPPORT SOFTWARE

1. <u>Amplitude Analysis</u> (<u>Timout</u>)

A graphical output is provided by this amplitude routine which displays the relative amplitude versus time for a selected sensor. The initial target direction and target classifications found are also displayed. This routine allows for the interactive selection of the

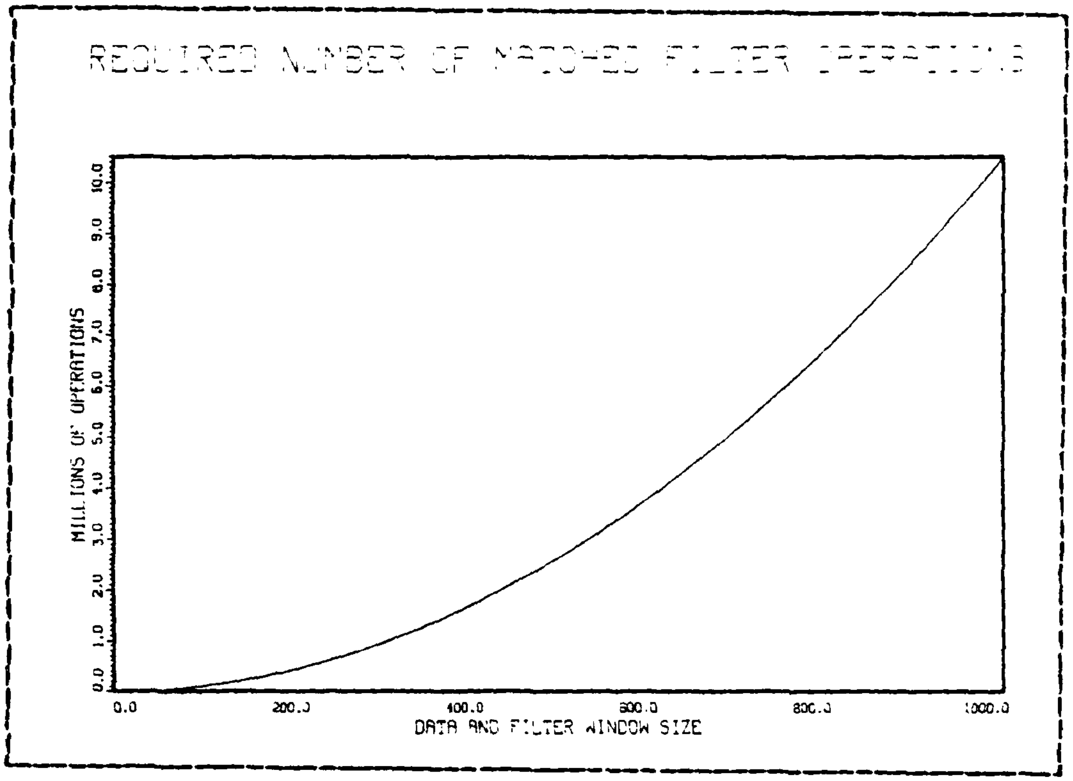

Figure 4.4 Data Window Size vs Number of Operations

amplitude response of any sensor as a sample target for later use in the matched filter analysis. In this way sample, signals can be catalogued and evaluated as filter signals. The axes of the graphical output adapts to the data's maximum amplitude and to the time period involved. Figure 4.5 is an example of amplitude analysis output.

2. Frequency Analysis (Freqct)

The frequency routine, as in the amplitude analysis routine, allows for initial primary target direction, target classifications, and for the time period of the experimental data to be displayed. Normalized spectral power versus frequency is graphically displayed as shown in figure 4.6.

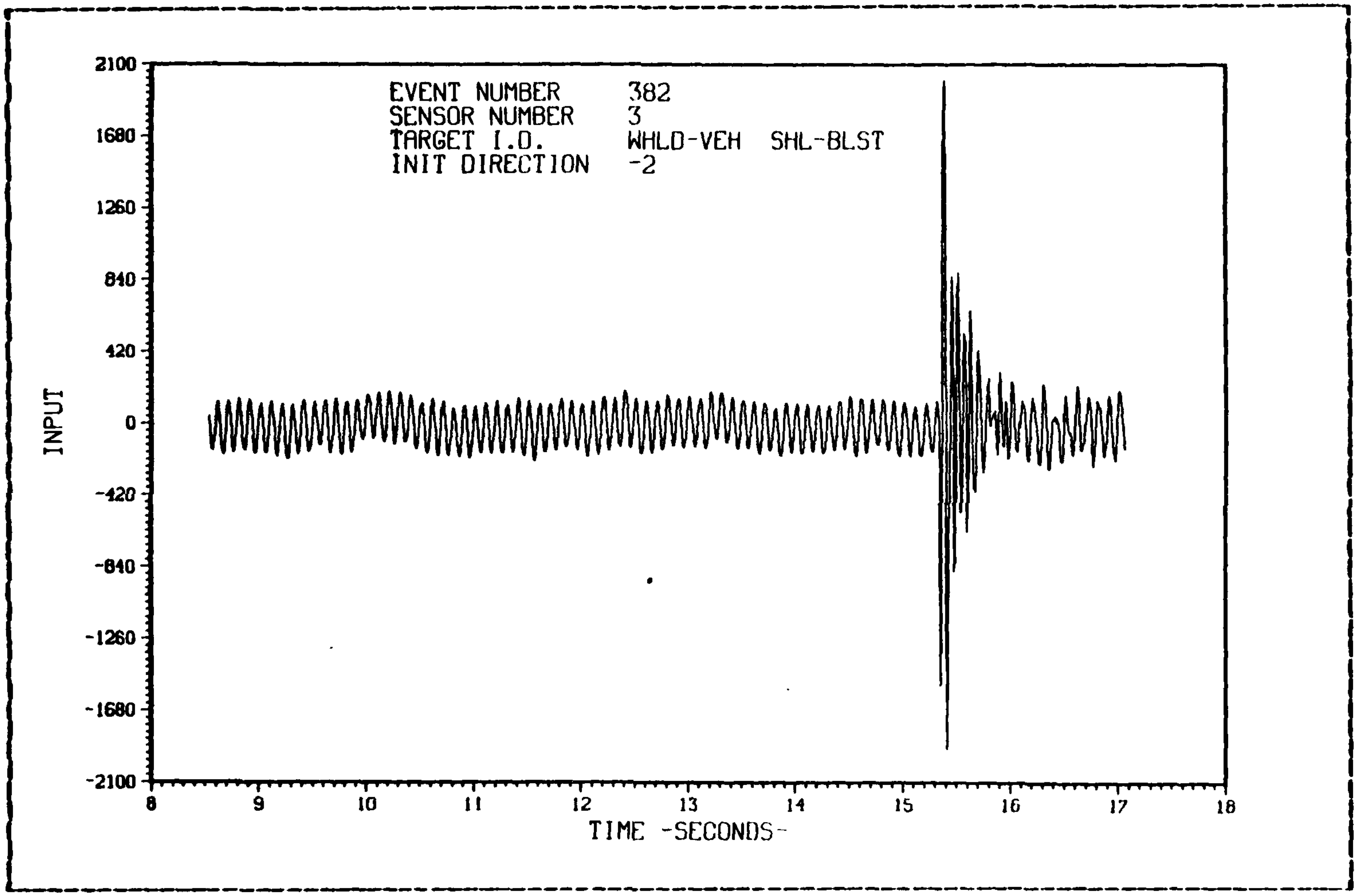

Figure 4.5 Sample Amplitude versus Time Output

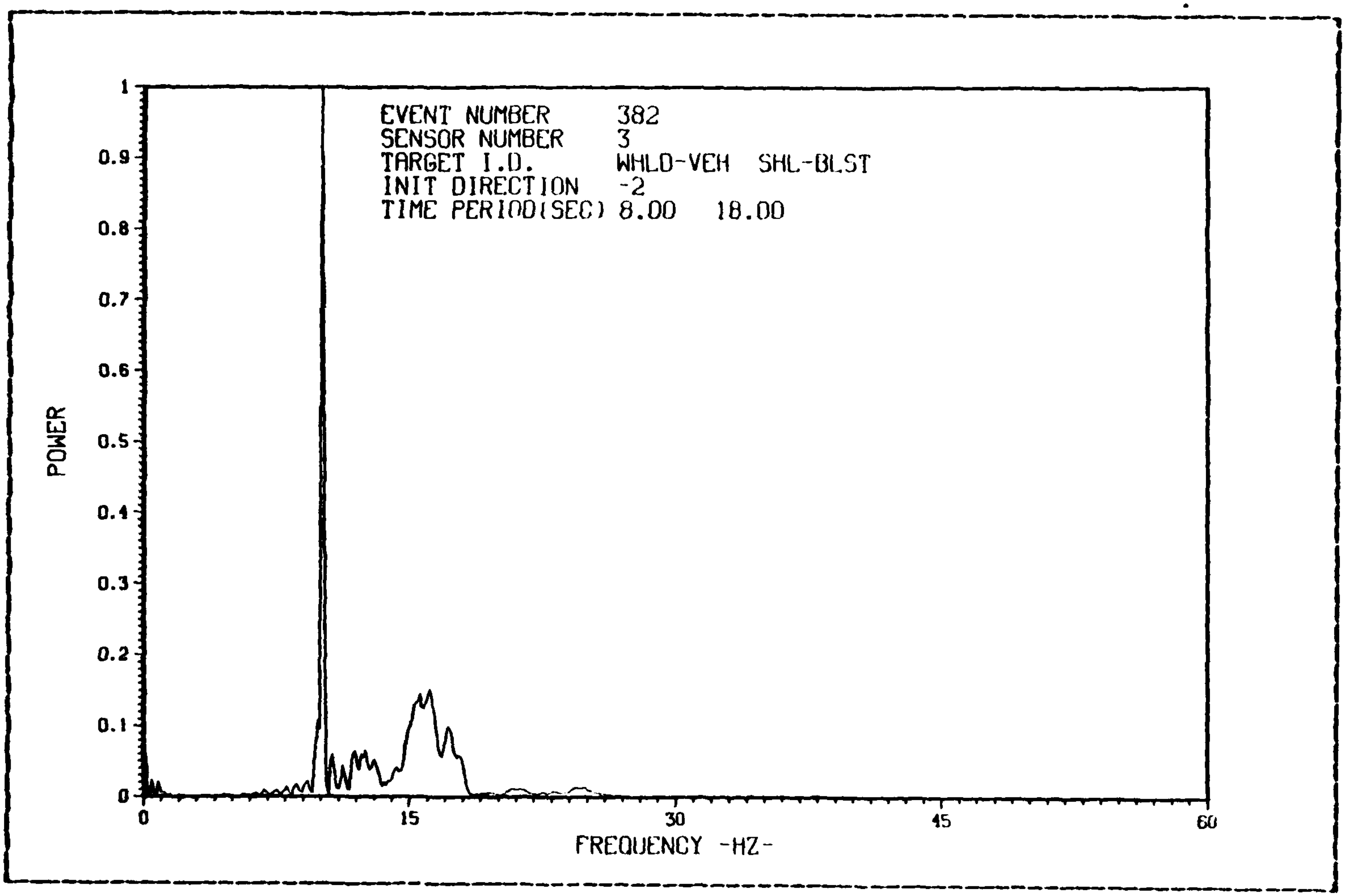

Figure 4.6 Sample Frequency versus Power Output

3. Simulation and Validation Software (SIMULT)

In order to validate the various algorithms and their implementation in software, a testing procedure was required. The specific algorithms which the simulation routine was designed to validate are the initial angle, phase difference and least mean square target direction routines. These routines, as previously described, use the relative time differences of the seismic signal's peak amplitude response or the peak matched filter response respectively. Validation of these routines is performed by allowing the creation of simulated targets with selected arrival angles.

Simulated targets can be created in the routine SIMULT. Up to four sine wave targets of selected frequency, amplitude, and direction can be input during each sample period. These simulated targets are added to the experimental seismic signal data for the sample period. Correspondingly, zero direction filter data must have been written into the matched filter data file at these selected sample target frequencies.

The directions for the simulated targets are created by introducing relative phase delays between the sine waves that are added to each sensor's seismic data. This is implemented by introducing a zero phase to the sensor in the desired direction of the simulated target. The phases of the other sensors are increased proportionally by their distance on the circular array away from the zero phase shift sensor. Figure 4.7 illustrates the case of a zero degree simulated target direction.

A summary of the target directions found by the multiple target direction routine and the simulated targets entered is provided by the multiple direction plotting routine. Figure 4.8 is a sample output.

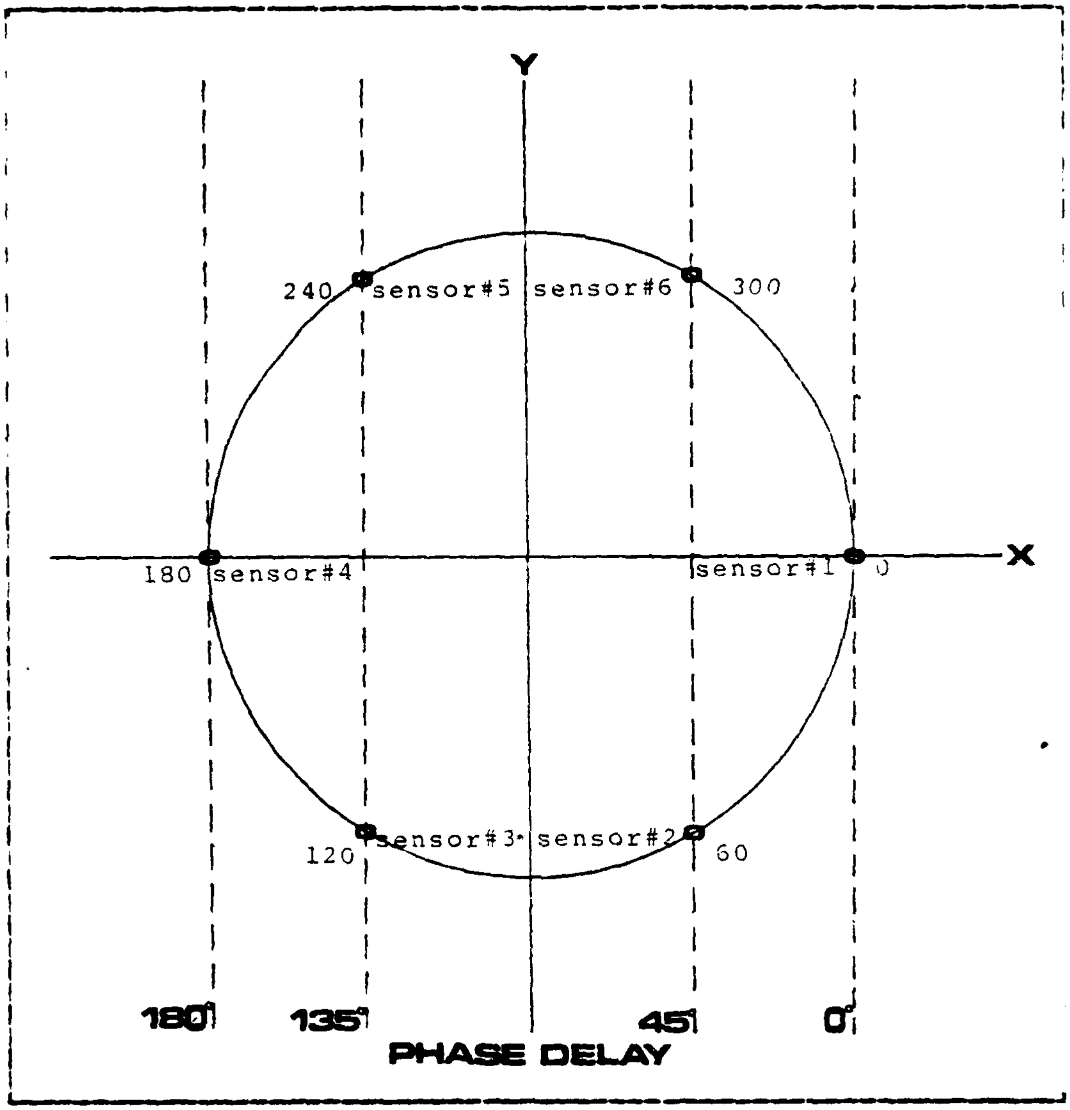

Figure 4.7   Simulation of a Zero Degree Target

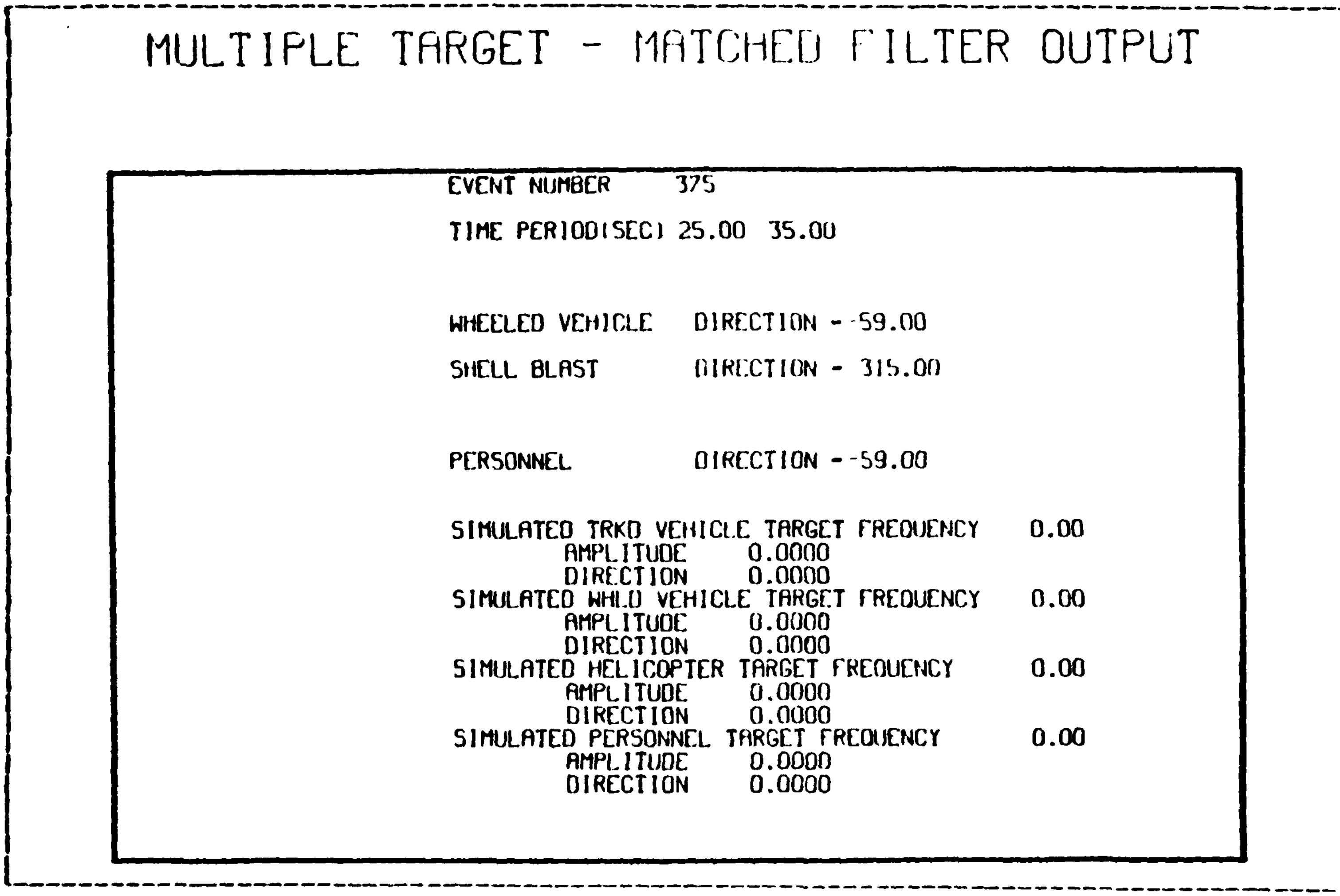

Figure 4.8 Sample Multiple Target and Simulated Target Output

V. MULTIPLE TARGET DIRECTION

A. THEORY AND DESIGN CRITERION

The modern battlefield is comprised of many classes and quantities of seismic signals. Using these signals for target identification and acquisition is the purpose of battlefield seismic sensors. As presented in the last chapter, matched filters can be used for target identification. In this chapter, it will be shown that matched filter information may also be used to obtain target bearing.

Multiple target acquisition requires the concurrent separation of the target classes and the computation of direction for each of the target classes found. The output of the matched filter is a spike at t_0, the time of peak signal detection. If matched filtering is performed for each of the sensors in the ring, the value of their respective t_0, for each filter output, would be different. Since the seismic waves impinge upon each sensor at different times, dependent upon the target direction, the values for t_0 for each sensor may be expected to be directly related to the arrival angle of the seismic wave. The t_0 spike of the matched filter output may be thought of as a signal compression for both the continuous (tank, truck etc.) and the time limited (shell blast, artillery recoil etc.) seismic signals [Ref. 6].

Time domain methods [Ref. 1] use the positional differences of known wave points to geometrically estimate direction. The times associated with a sensor ring's peak amplitude responses may be explained by way of an illustrative example of a shell blast. A rough direction to the origin of this shell blast can be computed using the

relative time differences associated with the peak amplitudes of all of the ring's sensors [Ref. 9].

The enhanced time positional information, which is a by-product of the matched filtering, can be used to perform just such a time domain approach. The motivation for the method is that, unlike other time and frequency domain methods, which are very susceptible to noise corruption inaccuracies, matched filtering pulls the signal out of the noise and optimally detects the signal at time t_o. Two time domain methods are evaluated for finding arrival angles of the seismic signal. The first being the time domain phase difference (TDPD) method. The second being a least mean squares polynomial (LMSP) curve fitting approach.

B. MULTIPLE TARGET FILTERING ALGORITHM (MULTI)

The routine MULTI calls the matched filter routine for each sensor's amplitude signal. Returned are the target classes found with their relative peak filter response positions. Figure 5.1 illustrates a two target case. The matched filter response and the relative time postion for the two classes of targets can be seen. The figure shows that a shell blast target is present. The relative time for this target class is 5800. The relative time returned for the simulated wheeled vehicle target is 3000. These times or positions are relative since each sensor's filter response peaks are offset in time with respect to the peaks of the other sensors. This allows for simultaneous direction finding for each class of target. This algorithm allows selection of either a time domain phase difference or or a least means square polynomial algorithm for finding the direction to the targets. The time domain phase difference algorithm is derived first [Ref. 1]. The least mean squares polyncmial direction algorithm then follows and is believed to be an orignial application to this field [Ref. 10].

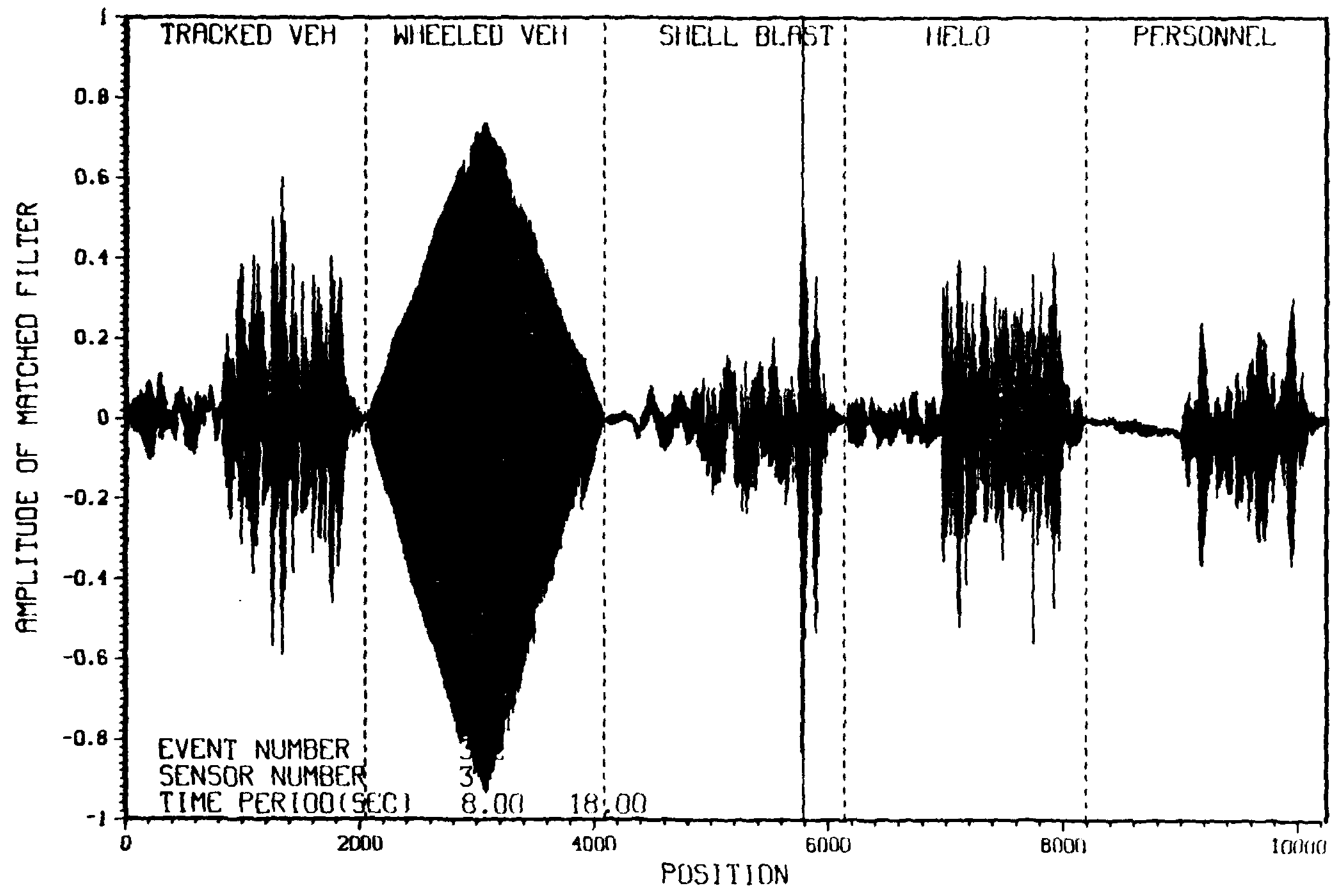

Figure 5.1 Two Target Matched Filter Response

1. Multiple Target Direction Phase Difference Algorithm

T_{ij} - the arrival time of the seismic signal at the I-th sensor for the J-th target class

θ_i - the angle of the I-th sensor to the x - axis

D_{ji} - the distance from the origin to where the wave front of the J-th target passes the I-th sensor

Tc_j - the time when the J-th target class passes the orgin

X_i, Y_i - the position of the I-th sensor

B_j - the arrival angle of the seismic wave for the J-th target class

V - the seismic wave velocity

R - the radius of the sensor ring

I - the sensor number where I has integer values form one to nine

J - the J-th target class

N - the number of sensors in the ring

Figure 5.2 illustrates these parameters and their interdependence. The derivation of the algorithm follows:

$\theta_i = 2 (I - 1)/N$

where zero degrees is set parrallel to the x - axis

$X_i = R\cos\theta_i$

$Y_i = R\sin\theta_i$

$D_{ji} = R\cos(\theta_i - B_j)$

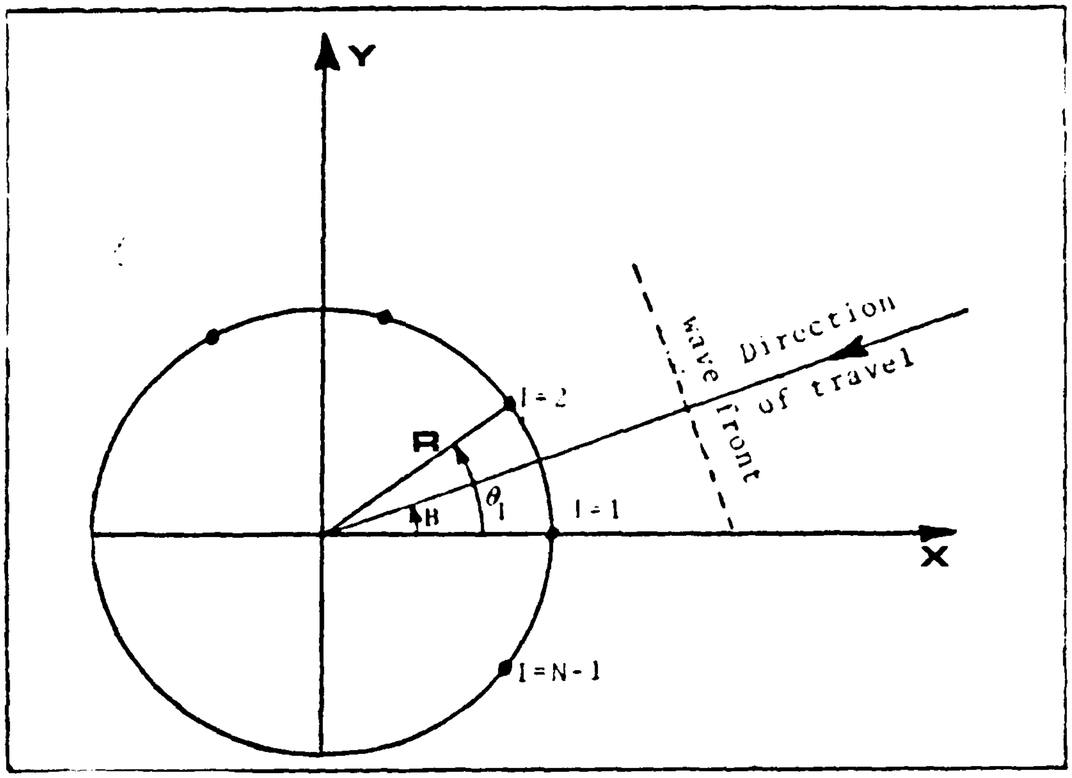

Figure 5.2 Circular Sensor Array Geometry

or equivalently $D_{ji} = (X_i)\cos B_j + (Y_i)\cos B_j$

$$Tc_j = (1/N)\sum_{i=1}^{N} T_{ji}$$

$$\tau_{ji} = Tc_j - T_{ji}$$

$$V = D_{ji}/\tau_{ji}$$

$$V = ((X_i)\cos B_j + (Y_i)\sin B_j)/(Tc_j - T_{ji}) \qquad (5.1)$$

Since the wave velocity can be assumed to be constant when passing all sensors, then for any sensor I and K where I ≠ K, equation 5.1 leads to

$$((X_i)\cos B_j + (Y_i)\sin B_j)/(Tc_j - T_{ji}) =$$
$$((X_i)\cos B_j + (Y_i)\sin B_j)/(Tc_j - T_{jk})$$

Where $I \neq K$

Now solving for the arrival angle B_{jik} of the wave

$$B_{jik} = \arctan(((Tc_j - T_{jk})X_i - (Tc_j - T_{ji})X_k)/ ((Tc_j - T_{ji})Y_k - (Tc_j - T_{jk})Y_i))$$

or equivalently;

$$B_{jik} = \arctan(((Tc_j - T_{jk})\cos\theta_i - (Tc_j - T_{ji})\cos\theta_k)/ ((Tc_j - T_{ji})\sin\theta_k - (Tc_j - T_{jk})\sin\theta_i))$$

Where the values of T_{ji} and T_{jk} are returned values from the matched filter routine.

Now;

$$B_j = (1/(N)^2)\sum_{i=1}^{N}\sum_{k=1}^{N} B_{jik}$$

Where B_j is the direction in radians to the J-th class target. For the multiple direction routine as implemented, 'j' has values from one to five.

2. Least Mean Square Polynomial Direction Finding

The least mean square direction finding algorithm was developed in response to problems encountered with the phase difference direction finding algorithm. This new method is base on a least mean squares polynomial curve fit of the sensor data. This approach was selected since the least mean squares polynomial provides for best fit or a maximum likelihood curve fit for noisy data.

The least mean squares direction finding algorithm, as with the phase difference algorithm, assumes the seismic wave to be planar. Figure 5.2 illustrates the parameters for this model. Once the assumption of a plannar seismic wave is made, the expected relation between the arrival

angle, relative delay times and sensor positon in the circular array, can be made. Figure 5.3 illustrates these relations for a nine sensor circular array with a seismic wave arriving at zero degrees. Notice that the relative delay times have been scaled to be from zero to one.

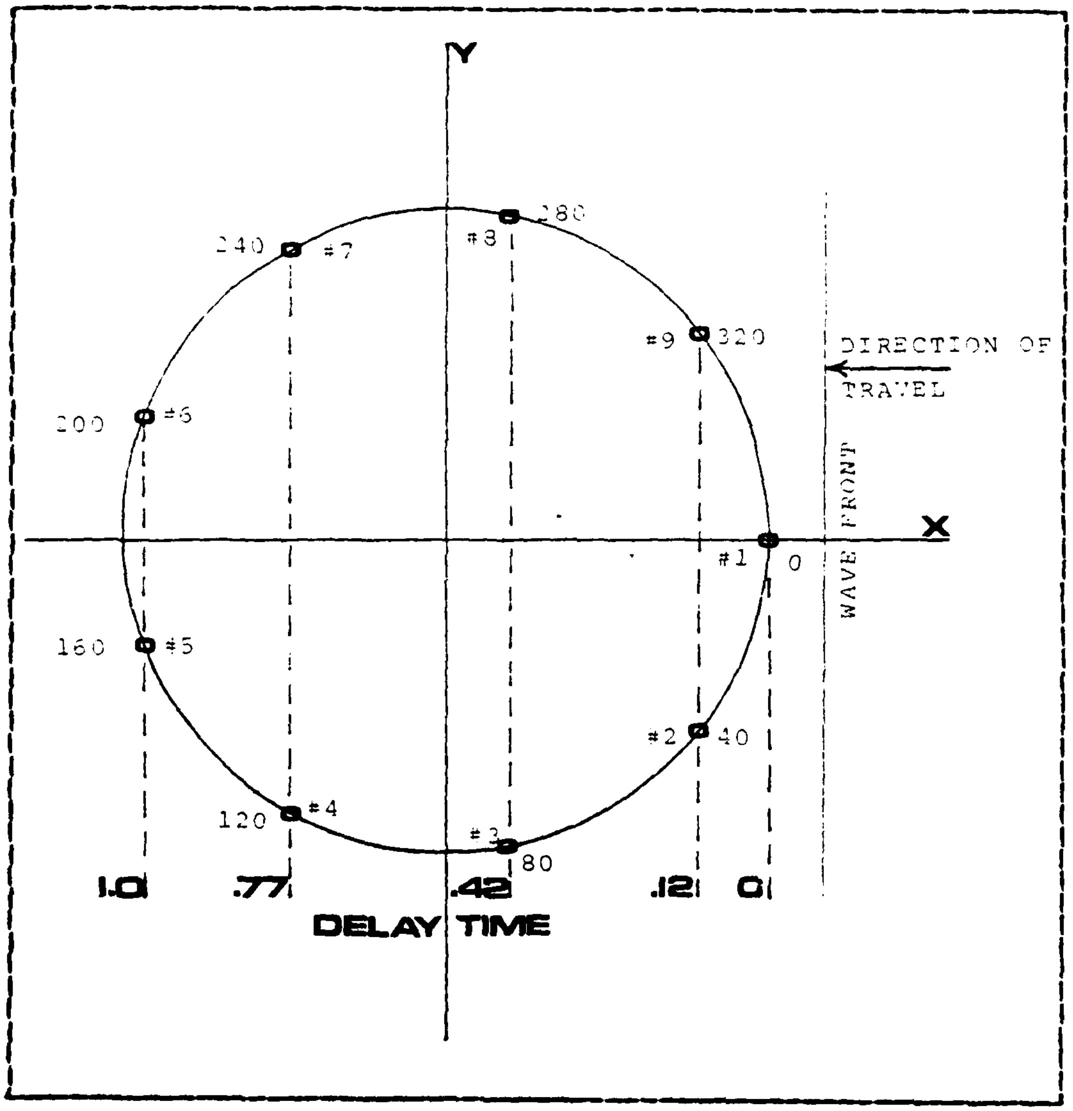

Figure 5.3 Relative Delay Times in a Nine Sensor Ring

Since the sensors in a nine sensor ring are at increments of forty degrees relative to the x-axis, a correlation can be seen between the relative time delays at each sensor and the arrival angle of the seismic wave. A plot can now be made to illustrate the relationship of sensor angles versus relative time delays. Figure 5.3 is a plot for a nine sensor ring with a plannar seismic wave arriving at zero degrees. Figure 5.4 shows that for a wave at an arrival angle of 160 degrees, the delay time at sensor number five will be zero. It can be seen that the fitting of these ideal data points with a least mean squares polynomial will produce an equation for a curve whose minimum value is also at the arrival angle of the seismic wave. The minimum degree of the polynomial to fit this ideal data is four. This results from noting that the curve in figure 5.4 has three curve inflections. For experimental data, this minimum curve point corresponds to the predicted arrival angle.

Polynomials of degrees higher than four may be expected to enhance arrival angle errors since the polynomial would distort to fit noisy data. Least means squares polynomials of degree two and three however, may be useful in reducing curve sensitivity to one or two malfunctioning sensors or excessively noisy data.

3. Least Mean Squares Polynomial Algorithm Derivation

Let:

N - number of data point pairs

Y_i - the observed or experimatal data position values

X_i - independent degree values with a range of 0 to 360 degrees

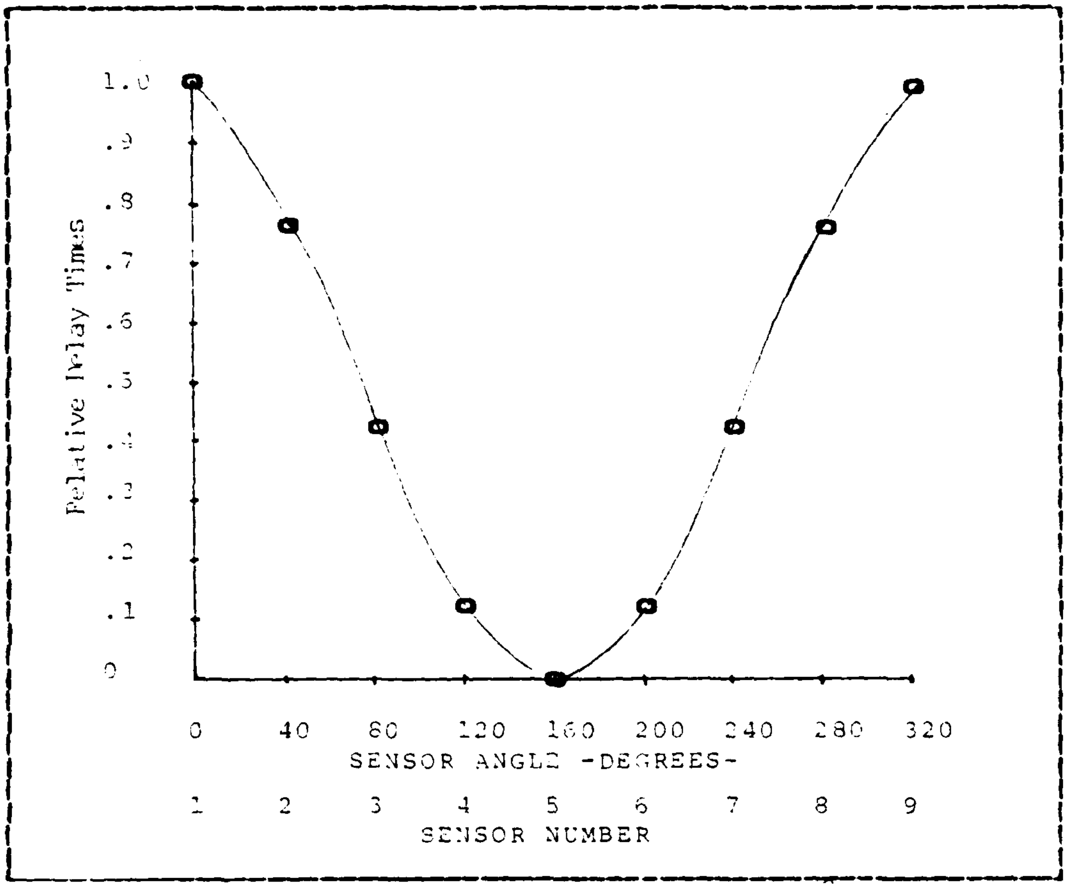

Figure 5.4 Relative Time Delay versus Sensor Angle

P_i - dependent predicted delay time values found by the least mean squares polynomial

A_i, B_i - coefficient values for the system of simultaneous equations

E_i - error between the experimental data values and predicted values of time delays

S - sum of the square errors between each data and predicted points

The derivation of the least mean squares polynomial follows:

$$S = E_1^2 + E_2^2 + E_3^2 + \ldots + E_N^2$$

$$P_i = A_0 + A_1X_i + A_2X_i^2 + A_3X_i^3 + \ldots + A_nX_i^n \tag{5.2}$$

$$E_i = Y_i - P_i \tag{5.3}$$

$$S = \sum_{i=1}^{N} E_i^2 \tag{5.4}$$

Combining equations 5.2 and 5.3 yields

$$E_i = Y_i - A_0 - A_1X_i - A_2X_i^2 - \ldots - A_nX_i^n$$

where n is the degree of the polynomial such that $N > n + 1$ and $1 < i < N$

Equation 5.4 now becomes, after substituting for E, equation 5.5

$$S = \sum_{i=1}^{N}(Y_i - A_0 - A_1X_i - A_2X_i^2 - \ldots - A_nX_i^n)^2 \tag{5.5}$$

To find the minimum of the sum of the squares expressed by equation 5.5, the partial derivatives of S with respect to all of the coefficients are taken. At the minimum, these partial derivatives all vanish.

$$\partial S/\partial A_0 = 0 = \sum_{i=1}^{N} 2(Y_i - A_0 - A_1X_i - \ldots - A_nX_i^n)(-1)$$

$$\partial S/\partial A_1 = 0 = \sum_{i=1}^{N} 2(Y_i - A_0 - A_1X_i - \ldots - A_nX_i^n)(-X_i)$$

$$\vdots$$

$$\partial S/\partial A_n = 0 = \sum 2(Y_i - A_0 - A_1X_i - \ldots - A_nX_i^n)(-Y_i^n)$$

Dividing by two and rearranging gives n + 1 normal simultaneous equations. Expressed in matrix notation these equations become

$$
\begin{bmatrix}
N & \sum X_i & \sum X_i^2 & \cdots & \sum X_i \\
\sum X_i & \sum X_i^2 & \sum X_i^3 & \cdots & \sum X_i \\
\sum X_i^2 & \sum X_i^3 & \sum X_i^4 & \cdots & \sum X_i \\
 & \cdot & \cdot & & \cdot \\
 & \cdot & \cdot & & \cdot \\
\sum X_i^n & \sum X_i^{n+1} & \sum X_i^{n+2} & \cdots & \sum X_i^{2n}
\end{bmatrix}
\begin{bmatrix}
A_0 \\ A_1 \\ A_2 \\ \\ \\ A_n
\end{bmatrix}
=
\begin{bmatrix}
\sum Y_i \\ \sum X_i Y_i \\ \sum X_i^2 Y_i \\ \\ \\ \sum X_i^n Y_i
\end{bmatrix}
$$

The coefficient matrix in the above system of equations can be solved for. The minimum value for P_i can then be found. The X corresponding to this minimum value is declared to be the predicted arrival angle of the seismic wave. [Ref. 10]

4. Adaptive Target Direction Finding

An adaptive method is used to improve the directions found for all single target cases. To enhance the resolution accuracy of the peak filter output position, the single target seismic data is copied into the filter data section for its class of target. Subsequently, when the matched filter routine is called for each sensor, filtering is performed with sensor data from that time period.

5. Software features of the Multiple Target Direction Routine

As first addressed in the previous chapter, the multiple direction routine allows for the selection of the number of data points to be used from the 1024 size buffer of sensor data. This was included to investigate the algorithm's performance for various data/filter window sizes and to allow an option for reduced CPU time utilzation for interactive program runs. Tabular output from this routine includes the event number, the time period for the data, identification and directions for up to five target classes, and up to four simulated target specifications. Also, notice that the routine adapts to the number of sensors

specified for the ring. This was necessary since the experimental data included sensor rings of six and nine vertical sensors.

C. MULTIPLE TARGETS OF THE SAME TARGET CLASS

A limitation on the system, as presented up to this point, is its inablity to engage multiple targets of the same class. Discrete targets may appear as separate entities since the seismic signals generated by the two same class targets are not likely to be incident at the same time. This situation is greatly complicated for continuous time signals, such as tracked or wheeled vehicles. For such continuous time targets, mutual distortion would be the likely result.

An algorithm is needed to identify these multiple peaks without erroneously declaring elements in the same peak as targets. By using only the positive half of the matched filter output and performing data smoothing on the remaining points, a curve with its number of peaks equalling the number of targets present could be generated. Numerical methods for curve fitting or interpolation are available [Ref. 11.]. Polynomial curve fitting, Sterling's method and variations of Newton's method are only a few of the possible approaches applicable for equally spaced data. By differentiating the smoothed data, the peaks and valleys of the filter output can be found. The height of the curve corresponding to the points where the derivative is zero can now be compared to the selected matched filter threshold. This excludes the valley points and leaves the points remaining which correspond to the relative times of the same class targets.

This method is constrained by resolution of close proximity, time limited targets and near phase synchronization

of continuous targets. The variables to be optimized through experimentation may be the degree of the smoothing of the curve data and the exclusion of erroneous valleys associated with the same target's data.

VI. ANALYSIS OF SEISMIC DATA

Analysis of the simulated and experimental seismic data will be conducted as detailed in Table II. Table III lists the matched filter contents for the simulated data. Table IV is the test plan for the experimental data. Table V lists the matched filter signals used for the experimental data analysis.

Table VI summarizes the results of the simulted and experimental data runs for direction finding. The window size, used for all multiple target direction finding results, was 300. Table VII lists the events in which targets were missed or incorrectly identified.

The time domain phase difference directions found, are not presented for the reasons noted earlier. Errors of up to eighty degrees were not uncommon with this method.

Each event run will be accompanied by the following graphic output:

1. Least Mean Square Initial Direction
2. Matched Filter Response
3. Amplitude Response
4. Amplitude Response of any Malfunctioning Sensor
5. Frequency Response
6. Least Mean Squares Polynomial Curve Fitting (LMSP) Using Matched Filter Outputs
7. Multiple Target Direction Summary Resulting from Least Mean Squares Curve Fitting

TABLE II

Test Plan for Simulated Data

Event	#Sen	#Tgts	Frequency	Amplitude	Direction
001	9	1	10	3000	0
001	9	1	10	3000	40
001	9	1	10	3000	120
001	9	1	10	3000	240

TABLE III

Matched Filter for Simulated Targets

Filter	Frequency	Amplitude	Direction
Tracked Veh	30	2000	0
Wheeled Veh	10	2000	0
Shell blast data from event #383			0
Helicopter	15	2000	0
Personnel	20	2000	0

TABLE IV

Test Plan for Experimental Data

Event	#Sen	#Tgts	Dir	Target	Distance
383	9	1	0	Shot	5KM
382	9	1	0	Shot	5Km
372	6	1	315	Helicopter	5 - 15KM
375	6	1	0	Tank	5 - 0Km
374	6	1	315	Helicopter	15 - 5KM
302	6	1	0	Mortar	1KM
314	6	1	315	LVT	4 - 5KM
354	6	5	0 225 315 0	105mm How 175mm Gun LVT M-60 Tank	5Km 4KM 4 - 5KM 4 - 5KM

TABLE V

Matched Filter for Experimental Data

Target	Event Used as Filter
Tracked Vehicle	375
Wheeled Vehicle	none (backround noise)
Blast/Recoil	383
Helicopter	372
Personnel	none (backround noise)

TABLE VI

Summary of Direction Finding Results

Event	#Sen	#Tgts	Distance	Dir	Initial Dif	%error	LMSP Dif	%error
001	9	1	N/A	0	N/A		0	0
001	9	1	N/A	40	N/A		40	0
001	9	1	N/A	120	N/A		120	0
001	9	1	N/A	240	N/A		240	0
383	9	1	5KM	0	4(3)	1.1	28(4) -5	7.8 1.4
382	9	1	5KM	0	-14(4)	3.9	-6	1.67
372	6	1	5 - 15KM	315	-32	3.6	-59	3.9
375	6	1	5 - 0KM	0	312	13.3	FAILED	
374	6	1	15 - 5KM	315	-59	4.0	FAILED	
302	6	1	1KM	0	4	1.1	6	1.7
354	6	5	5KM	0	-3	.8	3	.8
			4 KM	225	291	18.0	FAILED	
			4 - 5KM	315	FAILED			
			4 - 5KM	0	FAILED			

*Note: The matched filter threshold was set at .9 for all single targets and .6 for all multiple target events. Brackets indicate the use of other than a second degree polynomial.

TABLE VII

Missed or Incorrectly Identified Targets

Event	#Targets	Target	Nature of Errors
375	1	Tank	1. Matched filter was not based on a high S/N sample signal
374	1	Helo	2. Small seismic signal amplitudes
354	1	LVT	3. Malfunctioning sensor(s)
	1	Tank	
	1	175mm Gun	Sever clipping distortion of input signal

Note: The numbered error sources apply to all events listed.

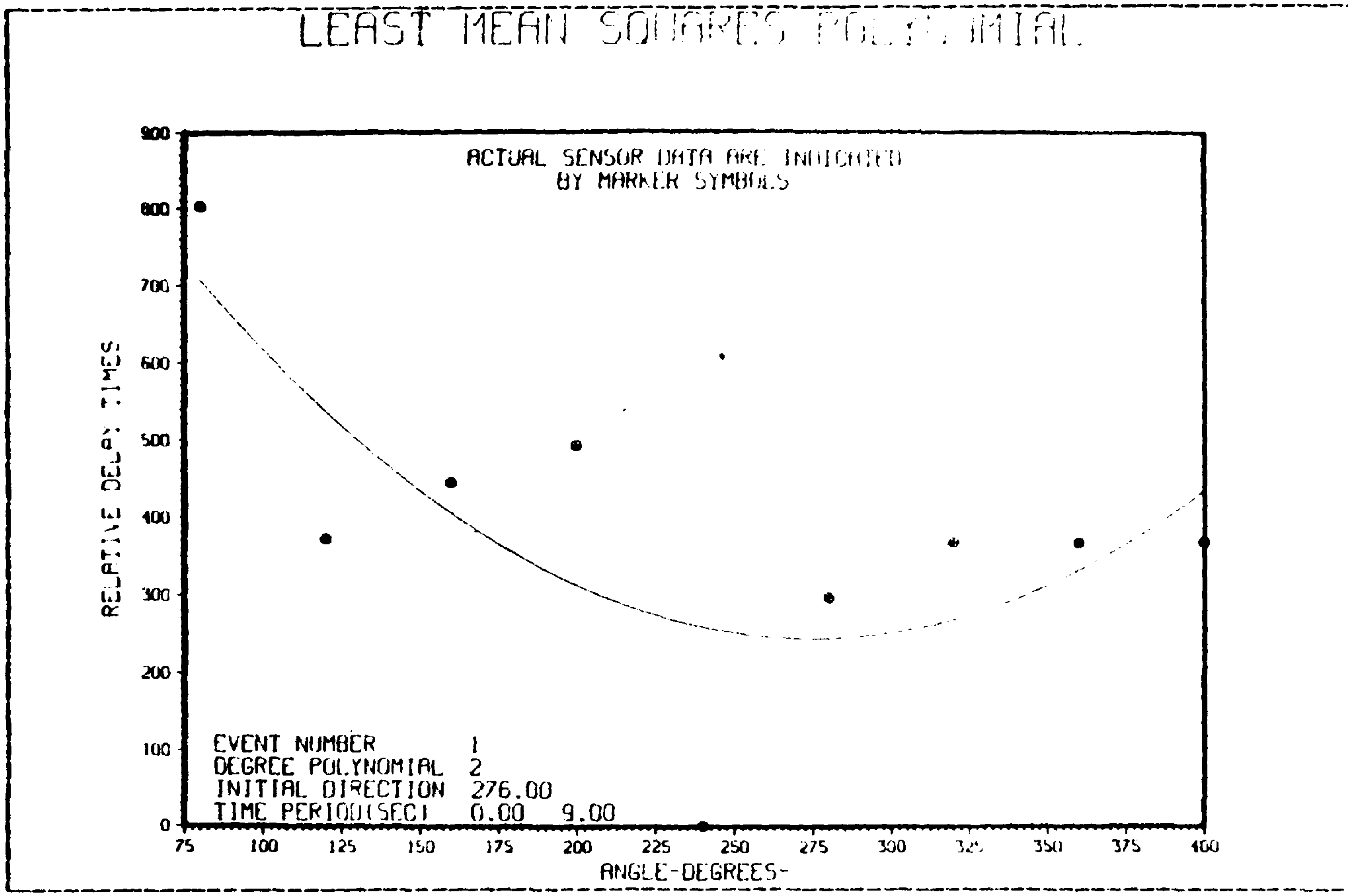

Figure 6.1 Sample Least Mean Squares Initial Direction for Event 001

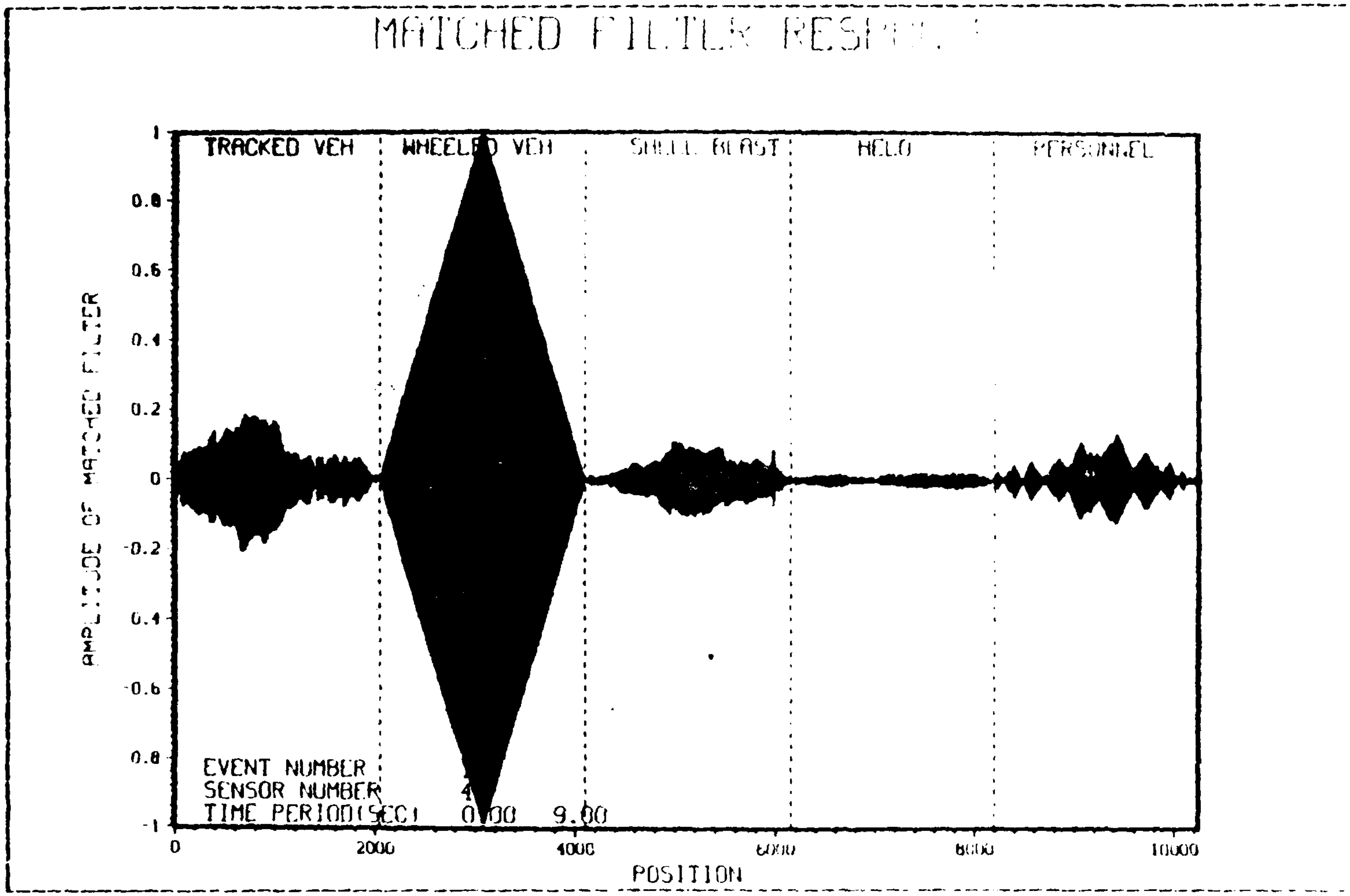

Figure 6.2 Sample Matched Filter Response for Event 001

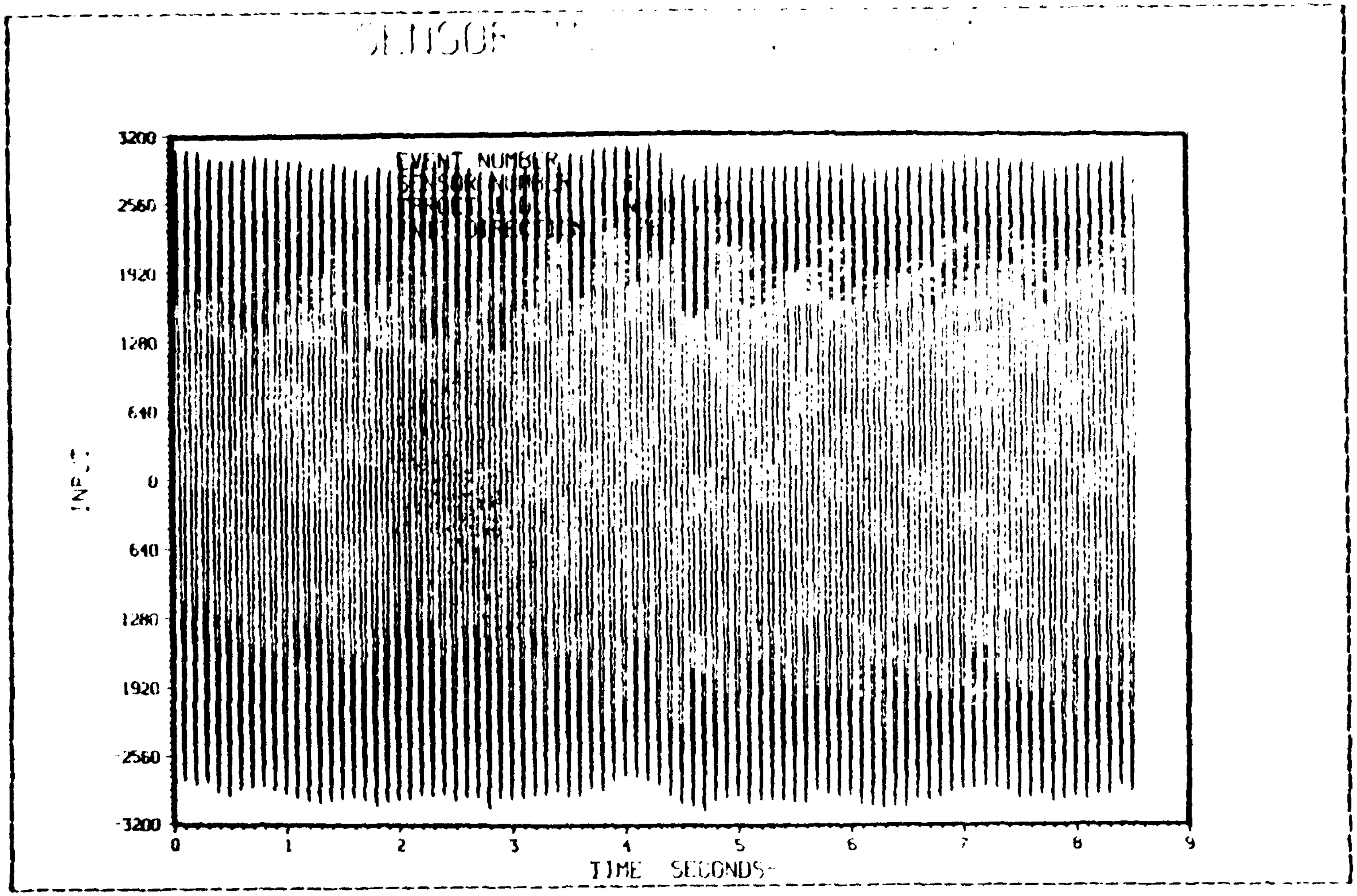

Figure 6.3 Sample Amplitude Response for Event 001

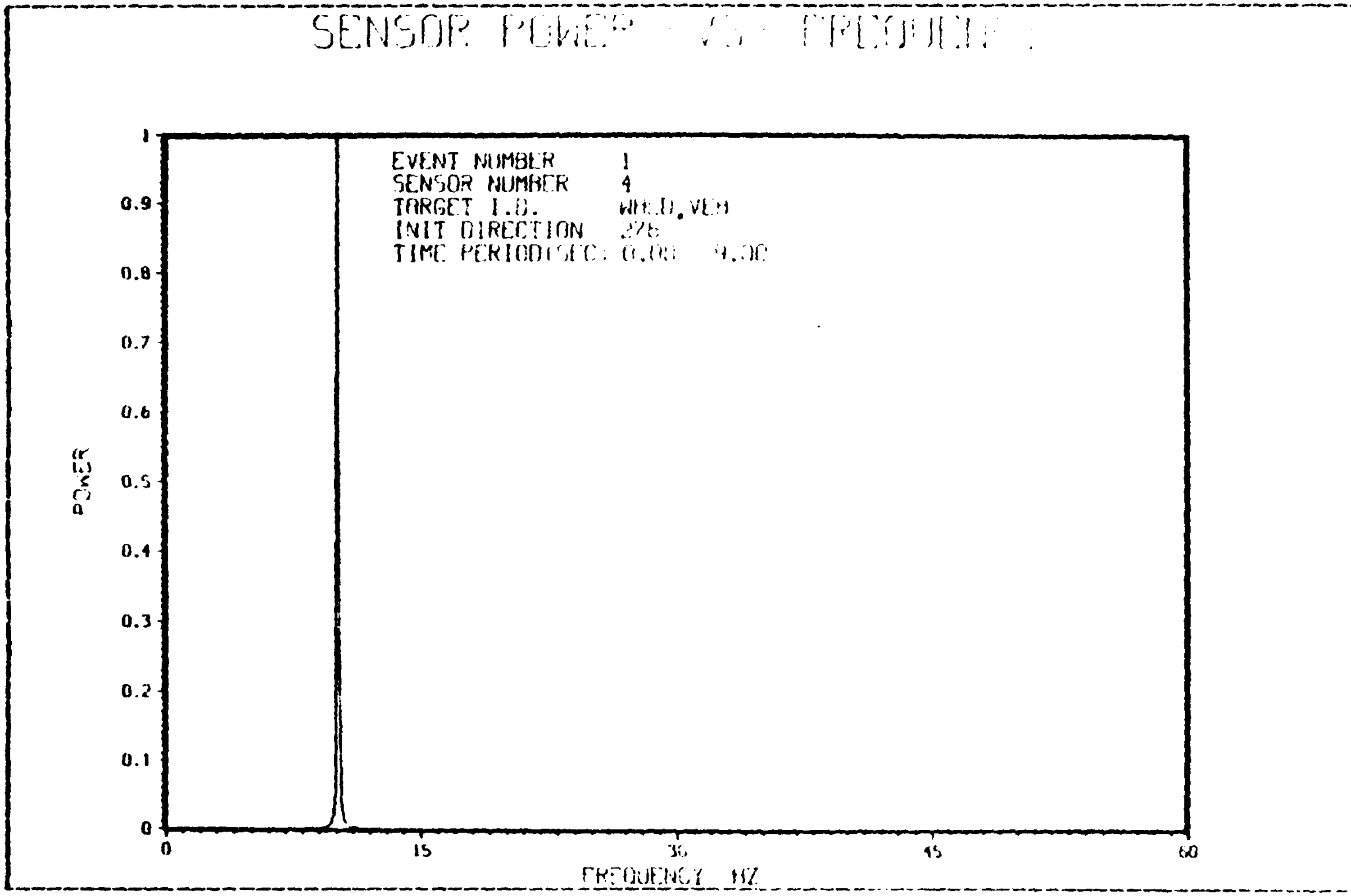

Figure 6.4   Sample Frequency Response for Event 001

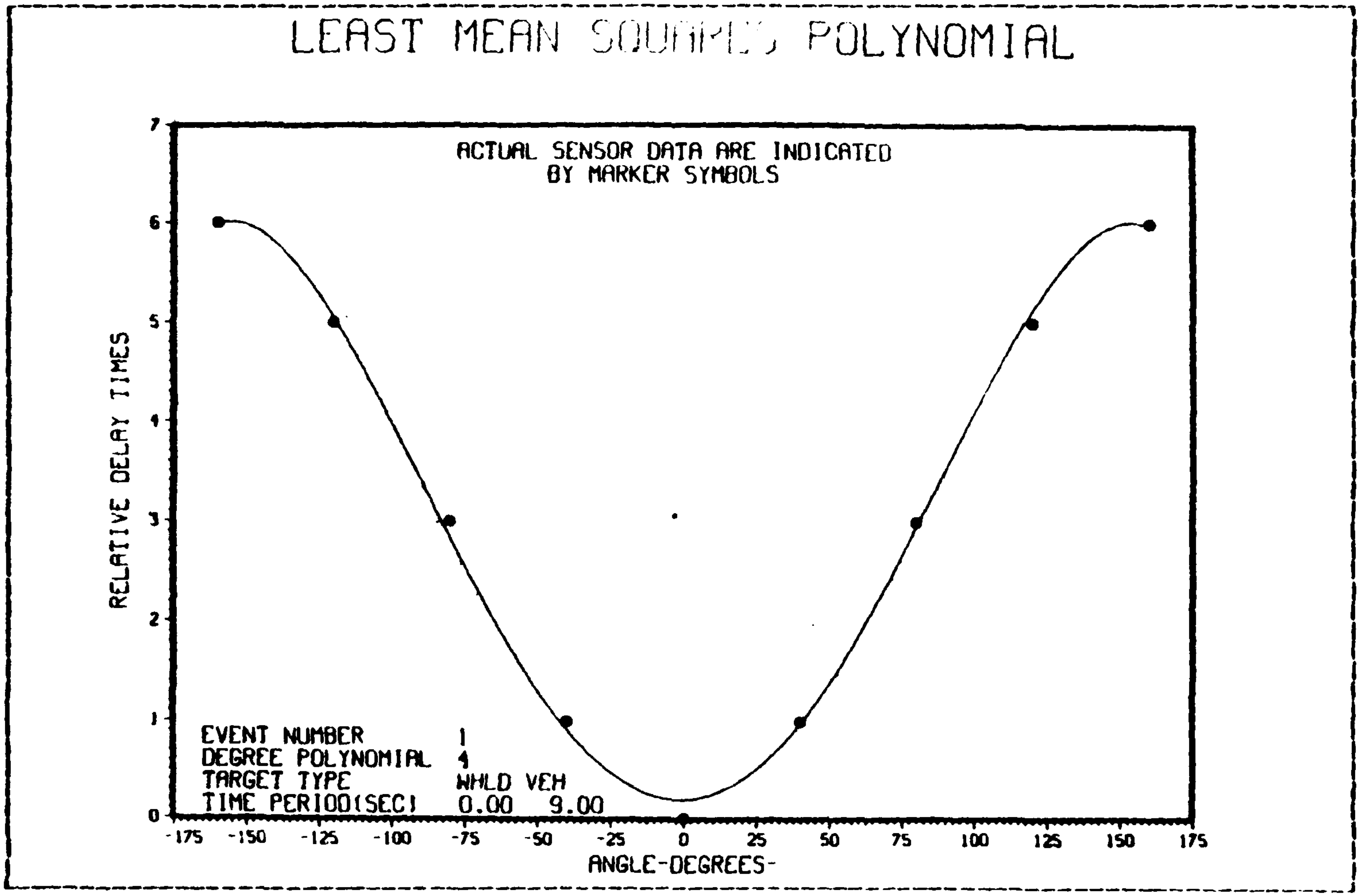

Figure 6.5 LMSP Matched Filter Direction for Event 001

MULTIPLE TARGET - MATCHED FILTER OUTPUT

```
EVENT NUMBER      1

TIME PERIOD(SEC) 0.00   9.00


WHEELED VEHICLE    DIRECTION - 0.00



SIMULATED TRKD VEHICLE TARGET FREQUENCY    0.00
          AMPLITUDE     0.0000
          DIRECTION     0.0000
SIMULATED WHLD VEHICLE TARGET FREQUENCY    10.00
          AMPLITUDE     3000.0000
          DIRECTION     0.0000
SIMULATED HELICOPTER TARGET FREQUENCY      0.00
          AMPLITUDE     0.0000
          DIRECTION     0.0000
SIMULATED PERSONNEL TARGET FREQUENCY       0.00
          AMPLITUDE     0.0000
          DIRECTION     0.0000
```

Figure 6.6   LMSP Multiple Target Direction Summary for Event 001

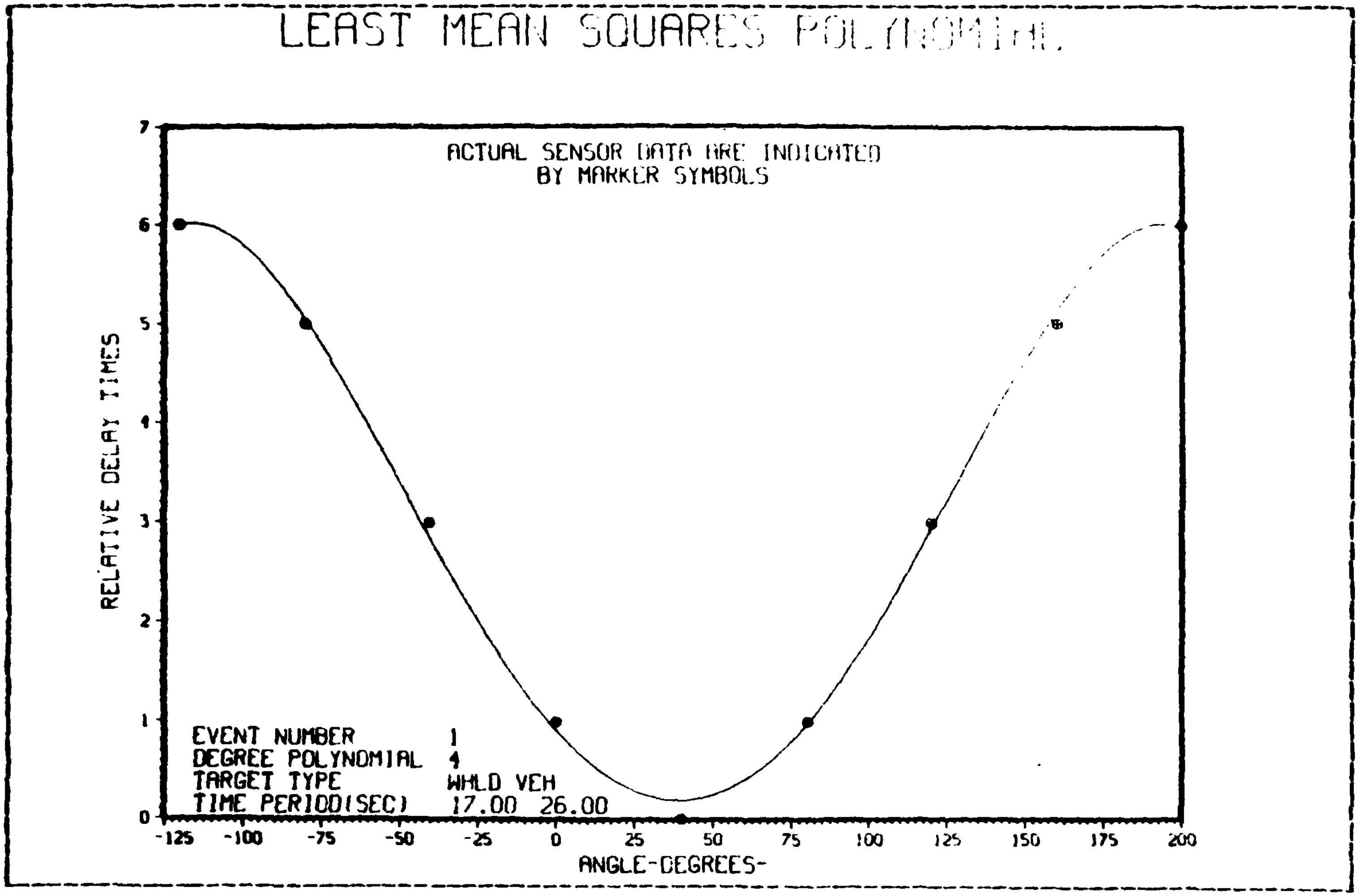

Figure 6.7 LMSP Matched Filter Direction for Event 001

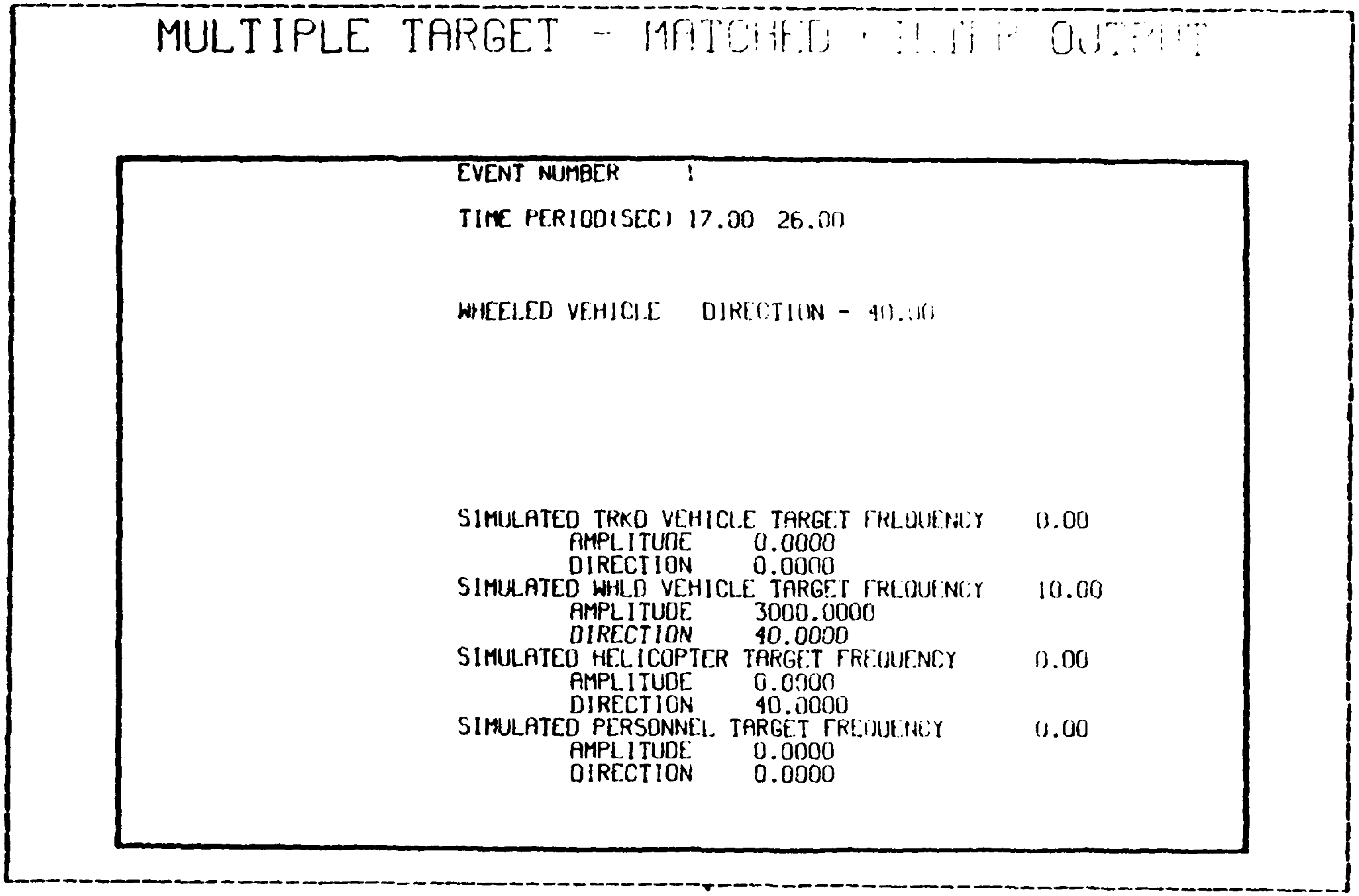

Figure 6.8 LMSP Multiple Target Direction Summary for Event 001

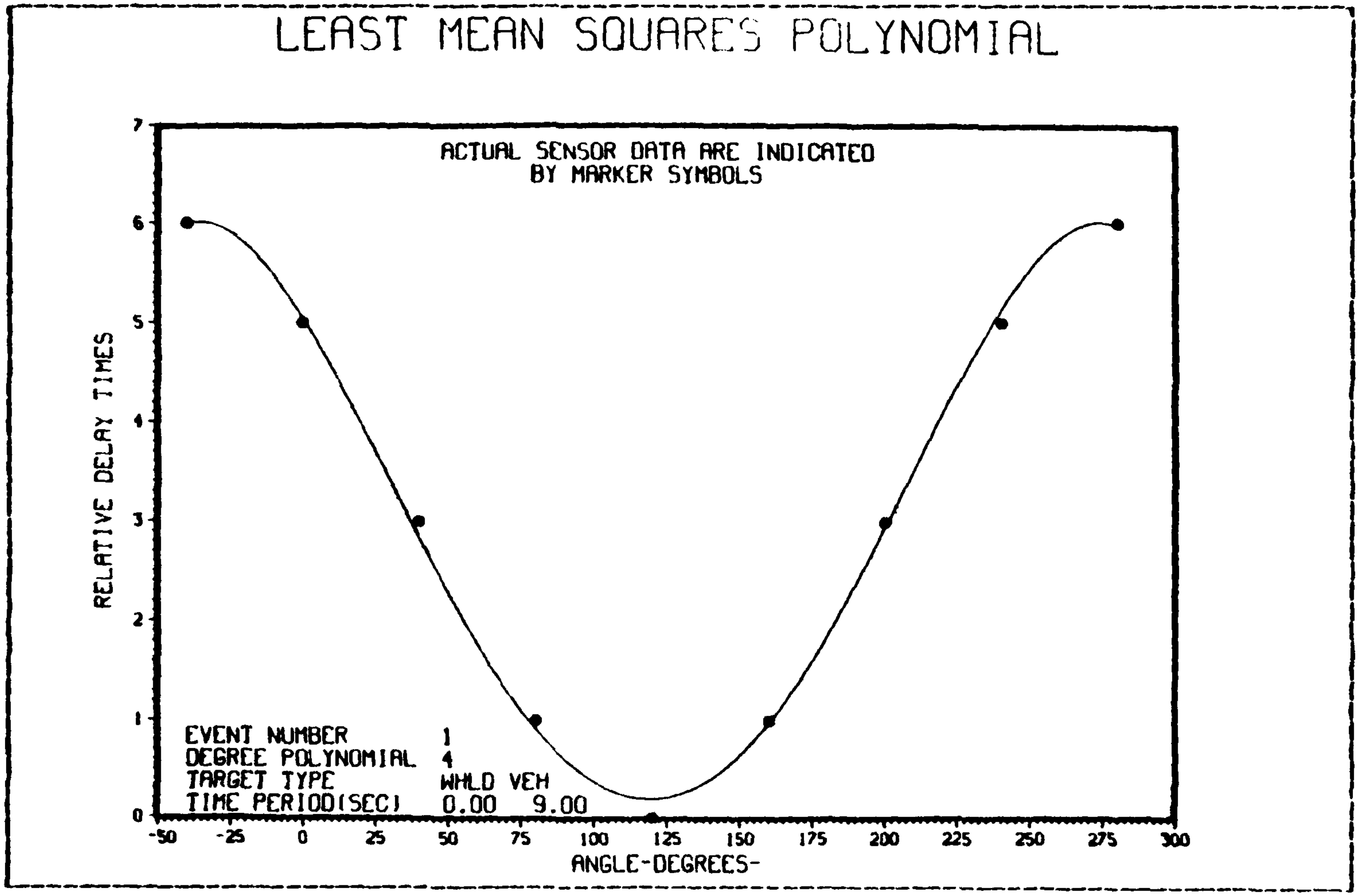

Figure 6.9 LMSP Matched Filter Direction for Event 001

```
MULTIPLE TARGET - MATCHED FILTER OUTPUT

EVENT NUMBER     1

TIME PERIOD(SEC) 0.00   9.00

WHEELED VEHICLE   DIRECTION - 120.00

SIMULATED TRKD VEHICLE TARGET FREQUENCY    10.00
          AMPLITUDE     3000.0000
          DIRECTION      120.0000
SIMULATED WHLD VEHICLE TARGET FREQUENCY     0.00
          AMPLITUDE       0.0000
          DIRECTION       0.0000
SIMULATED HELICOPTER TARGET FREQUENCY       0.00
          AMPLITUDE       0.0000
          DIRECTION       0.0000
SIMULATED PERSONNEL TARGET FREQUENCY        0.00
          AMPLITUDE       0.0000
          DIRECTION       0.0000
```

Figure 6.10 LMSP Multiple Target Direction Summary for Event 001

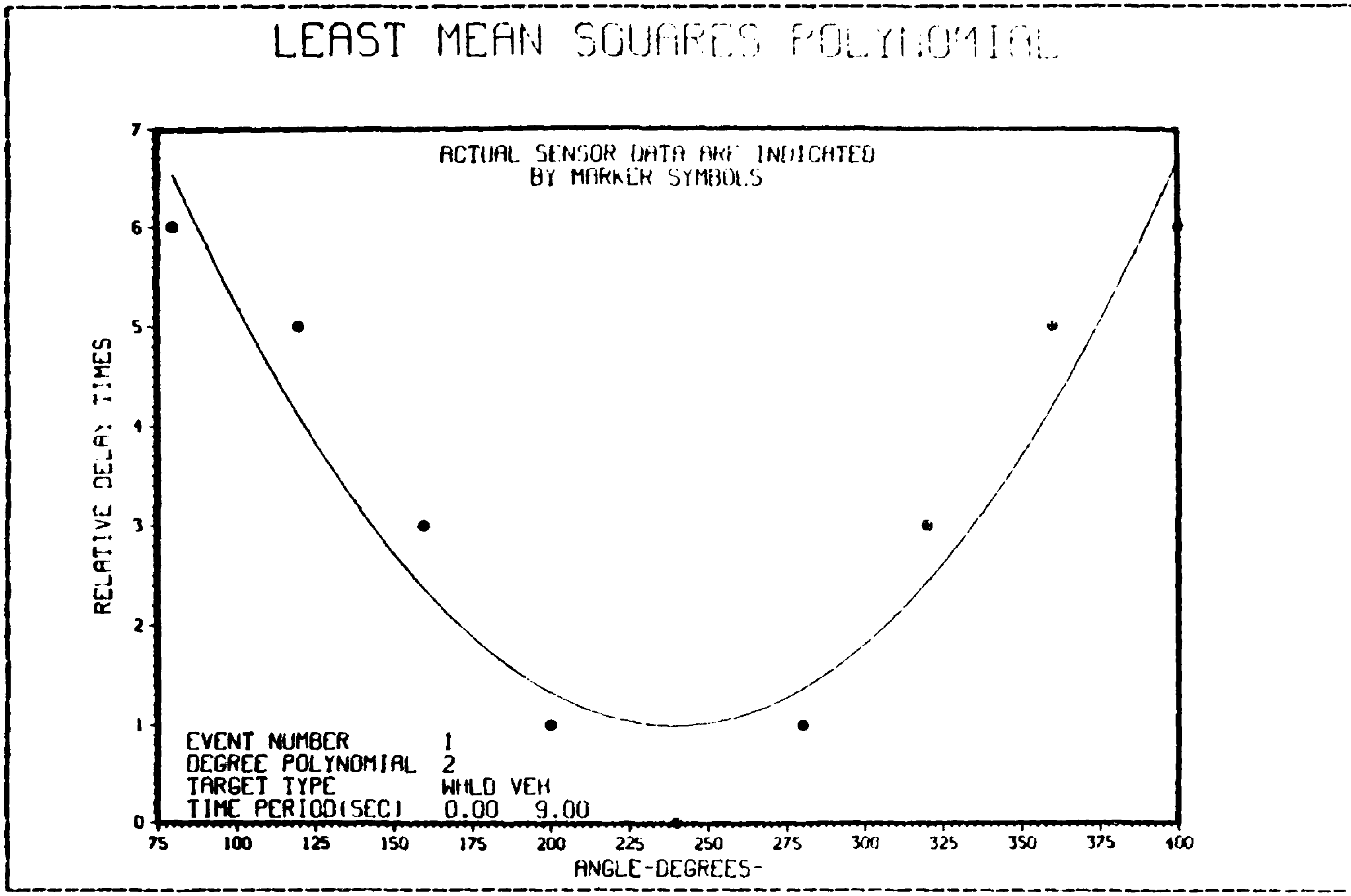

Figure 6.11 LMSP Matched Filter Direction for Event 001

MULTIPLE TARGET - MATCHED FILTER OUTPUT

```
EVENT NUMBER     1

TIME PERIOD(SEC) 0.00   9.00


WHEELED VEHICLE   DIRECTION - 240.00





SIMULATED TRKD VEHICLE TARGET FREQUENCY    0.00
          AMPLITUDE      0.0000
          DIRECTION      0.0000
SIMULATED WHLD VEHICLE TARGET FREQUENCY    10.00
          AMPLITUDE      3000.0000
          DIRECTION      240.0000
SIMULATED HELICOPTER TARGET FREQUENCY      0.00
          AMPLITUDE      0.0000
          DIRECTION      0.0000
SIMULATED PERSONNEL TARGET FREQUENCY       0.00
          AMPLITUDE      0.0000
          DIRECTION      0.0000
```

Figure 6.12 LMSP Multiple Target Direction Summary for Event 001

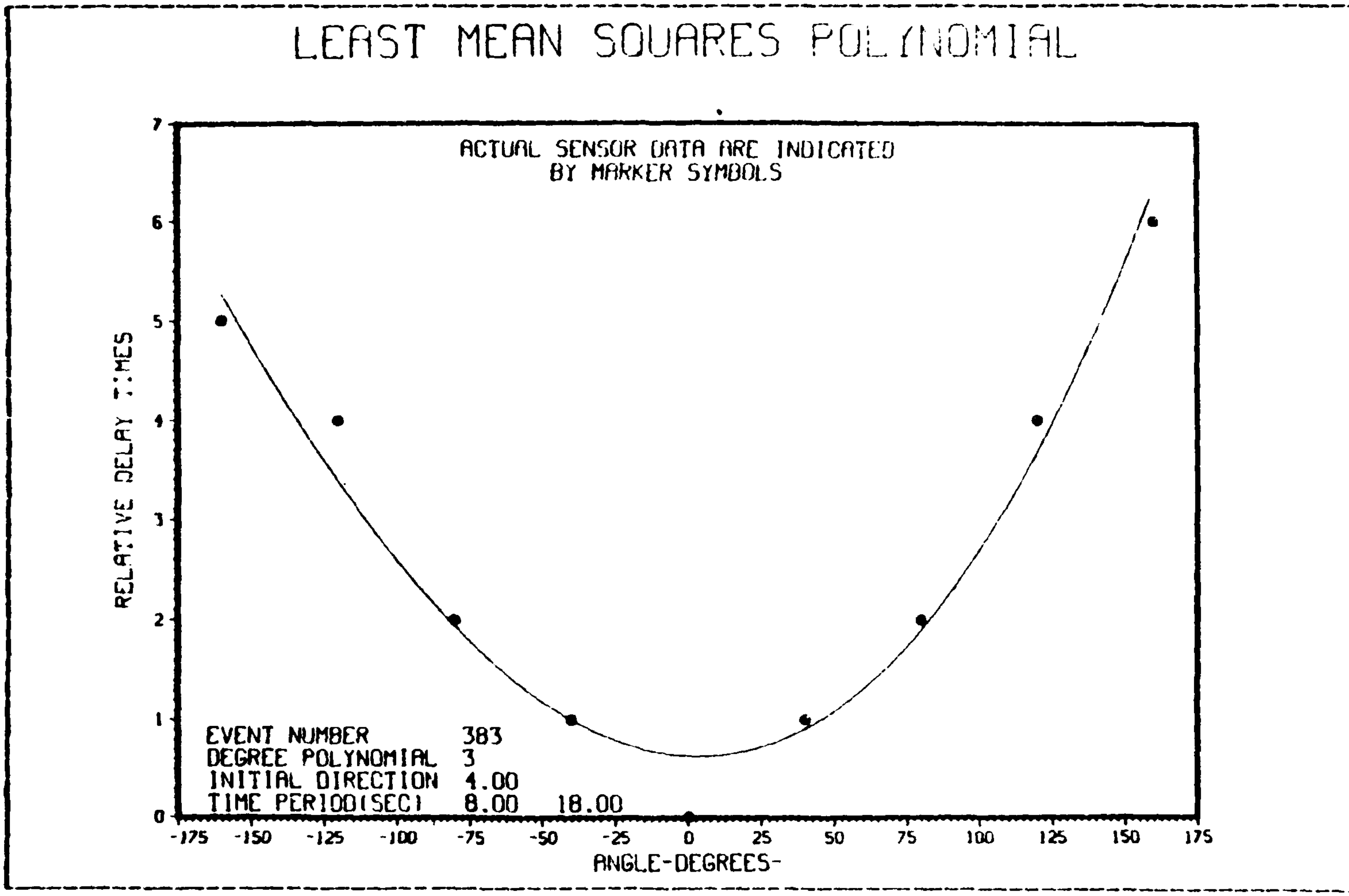

Figure 6.13 LMSP Initial Direction for Event 383

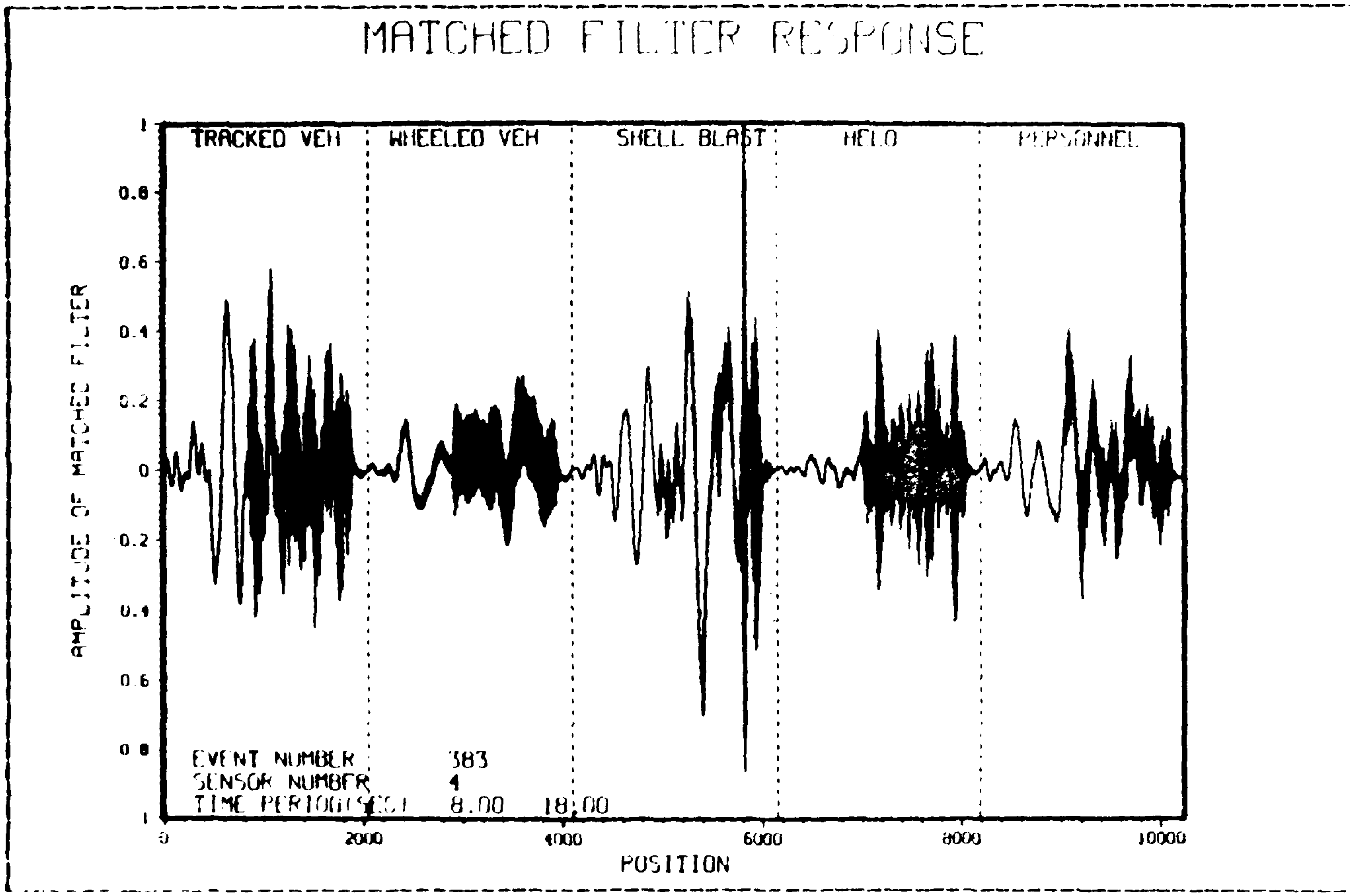

Figure 6.14 Matched Filter Response for Event 383

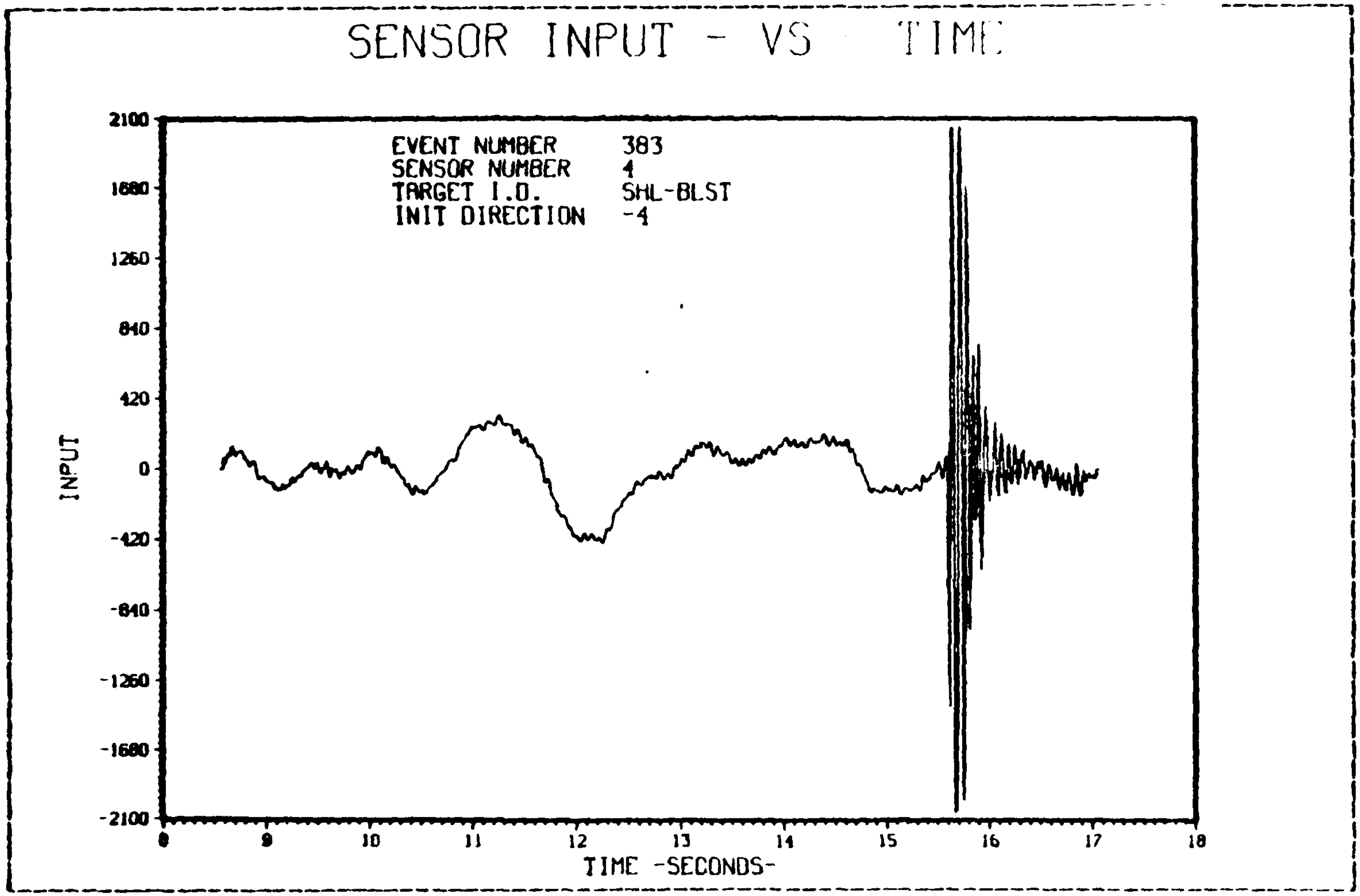

Figure 6.15 Amplitude Response for Event 383

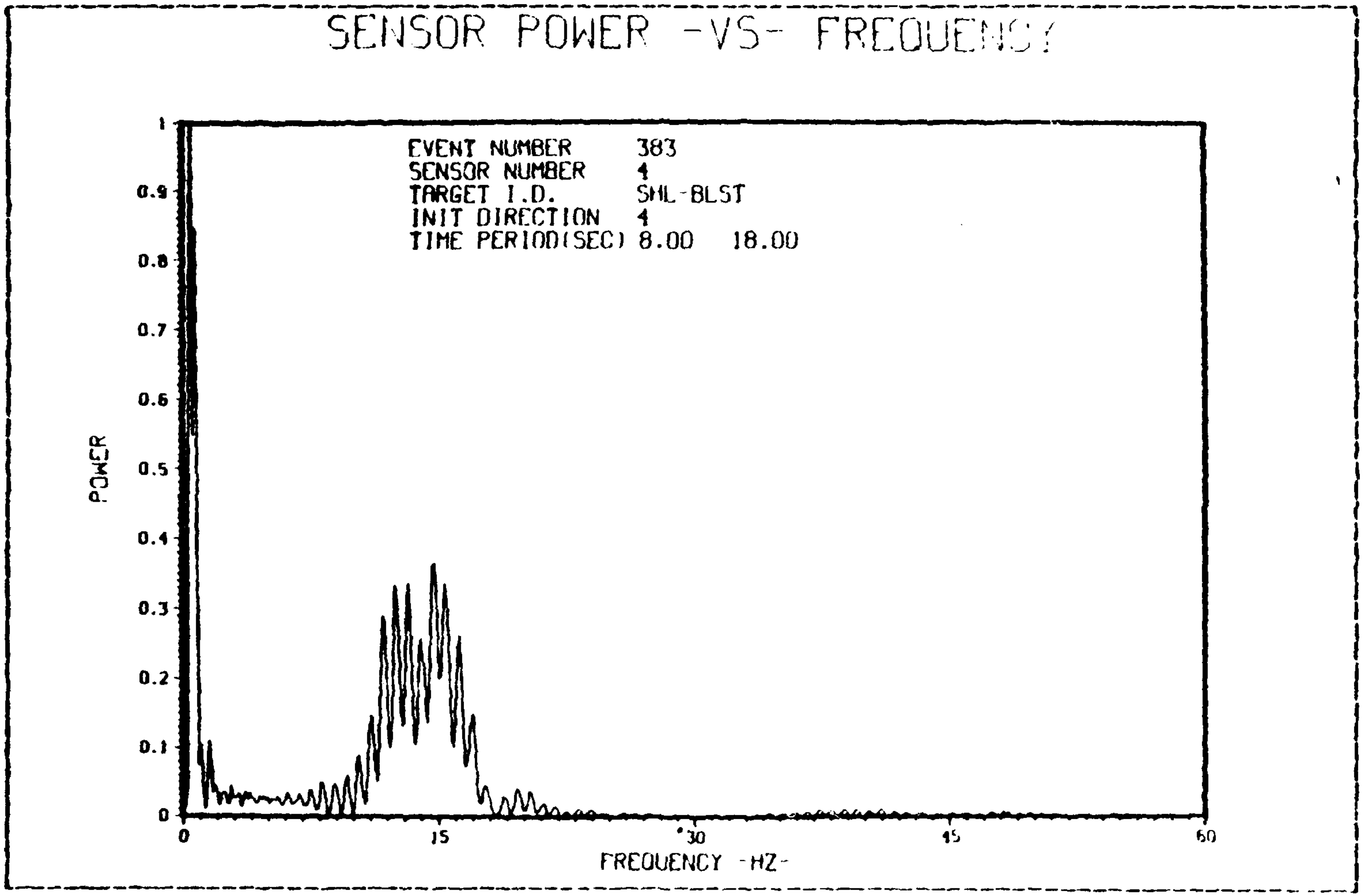

Figure 6.16 Frequency Response for Event 383

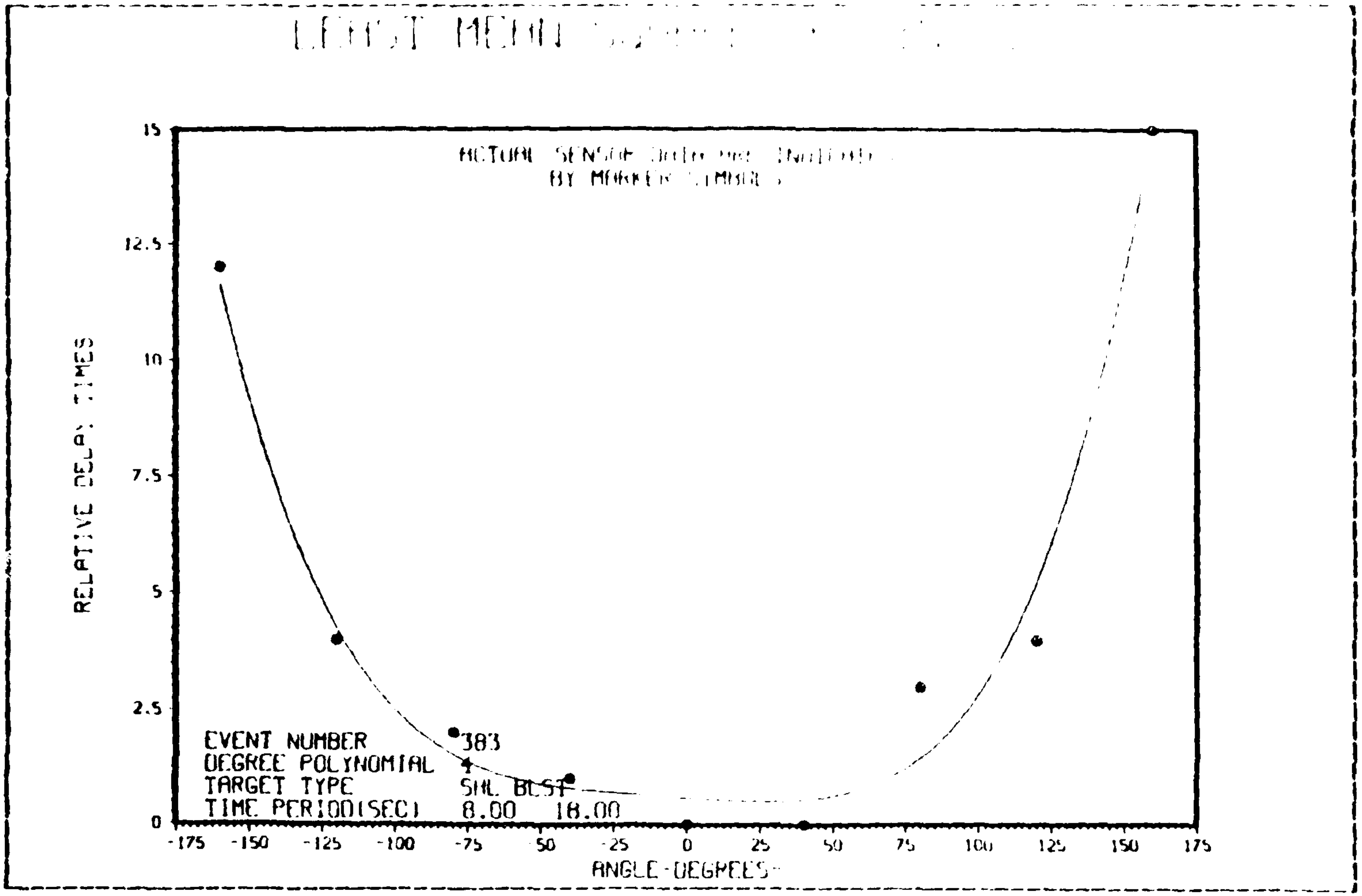

Figure 6.17 Fourth Degree LMSP Matched Filter Direction for Event 383

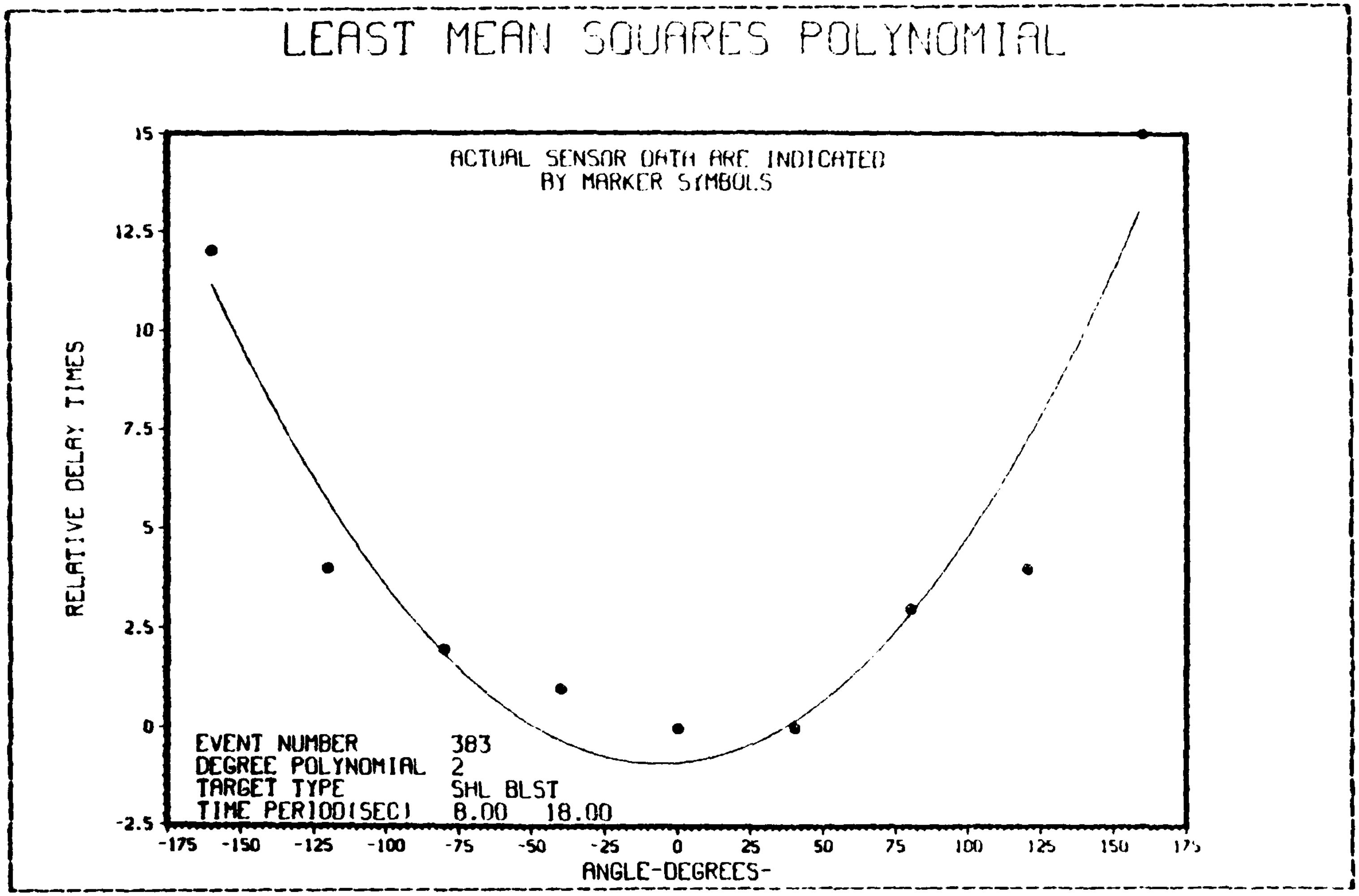

Figure 6.18 Second Degree LMSP Matched Filter Direction for Event 383

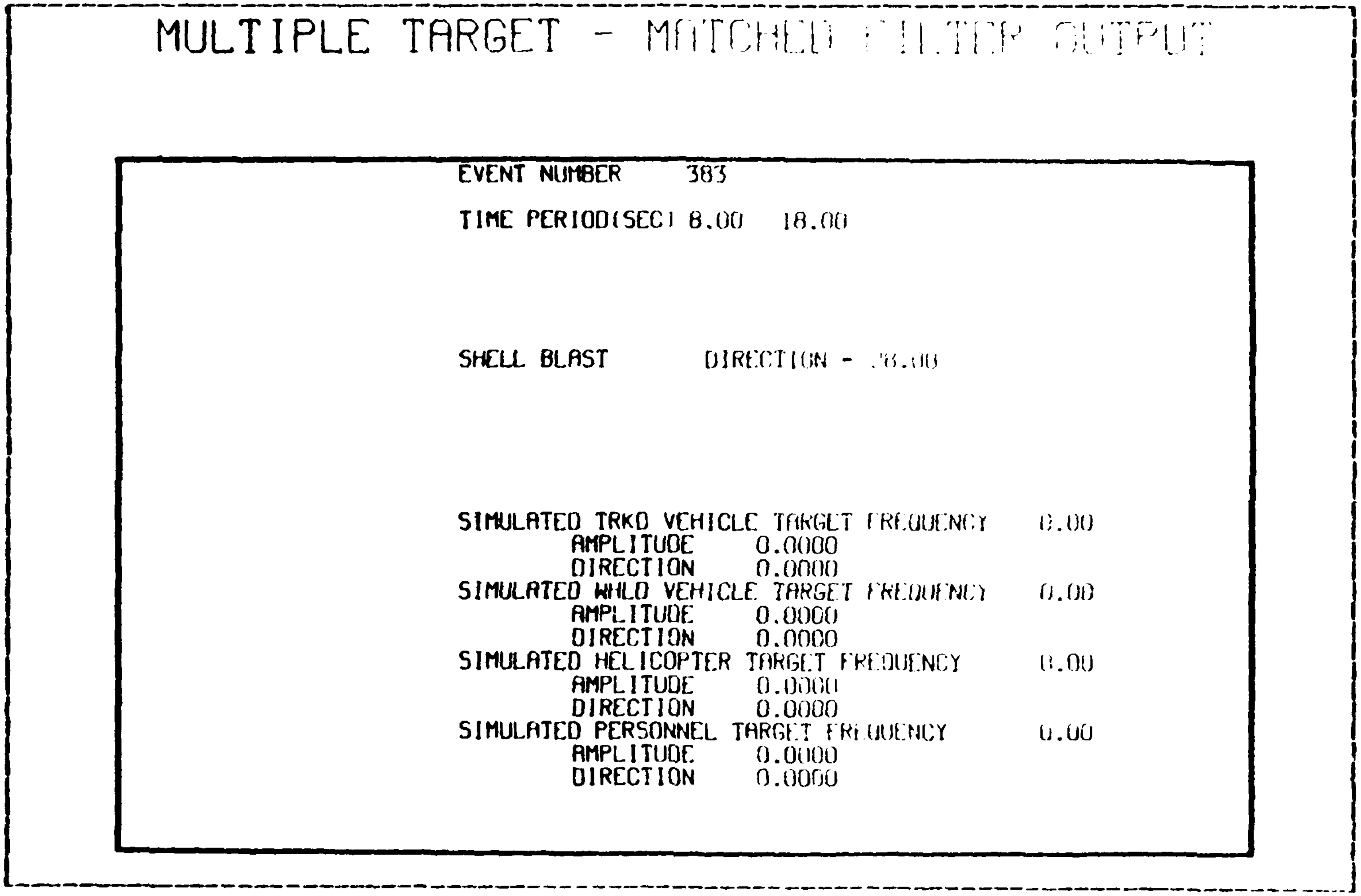

Figure 6.19 LMSP Multiple Target Direction Summary for Event 383

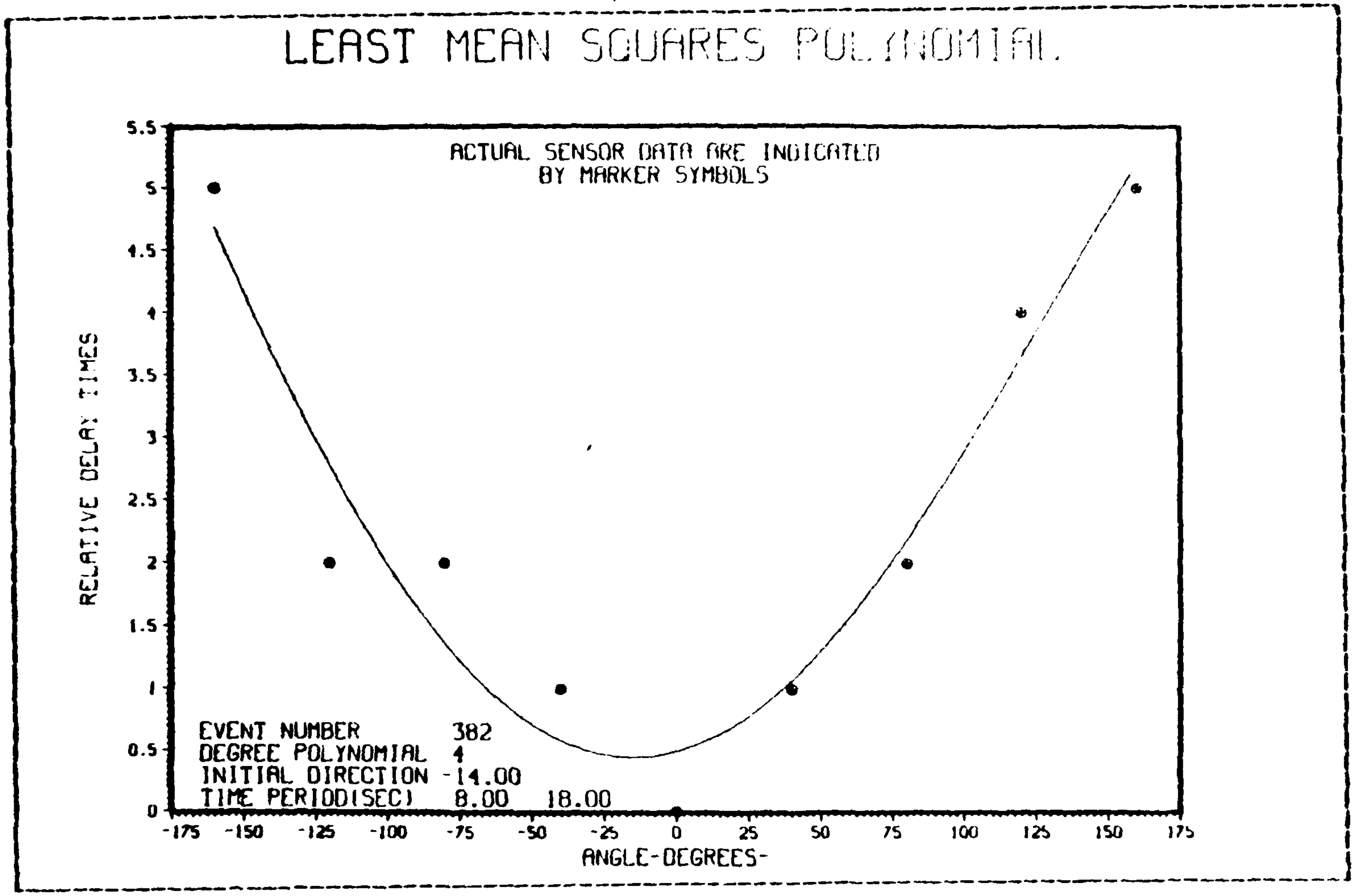

Figure 6.20 LMSP Initial Direction for Event 382

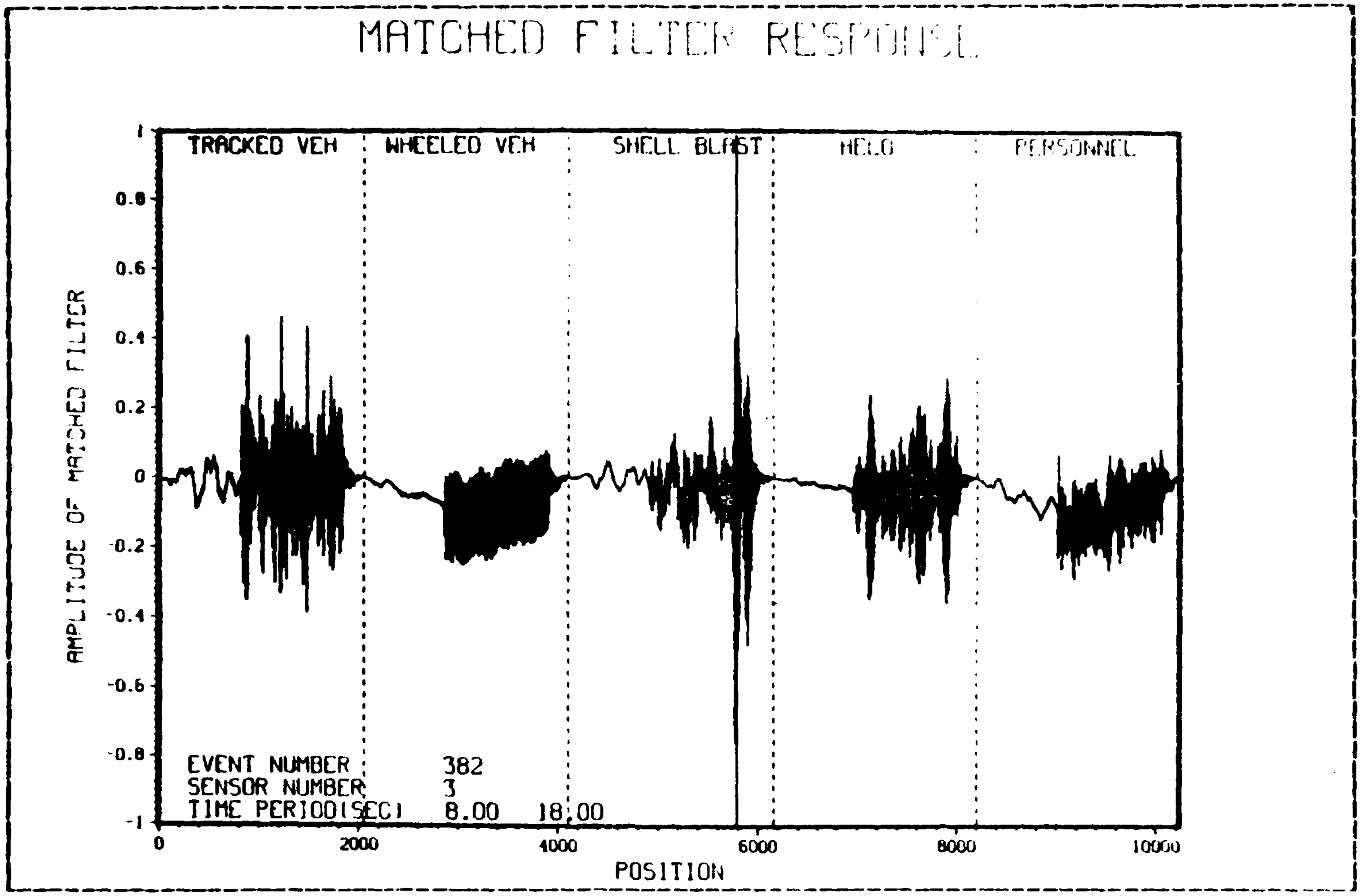

Figure 6.21 Matched Filter Response for Event 382

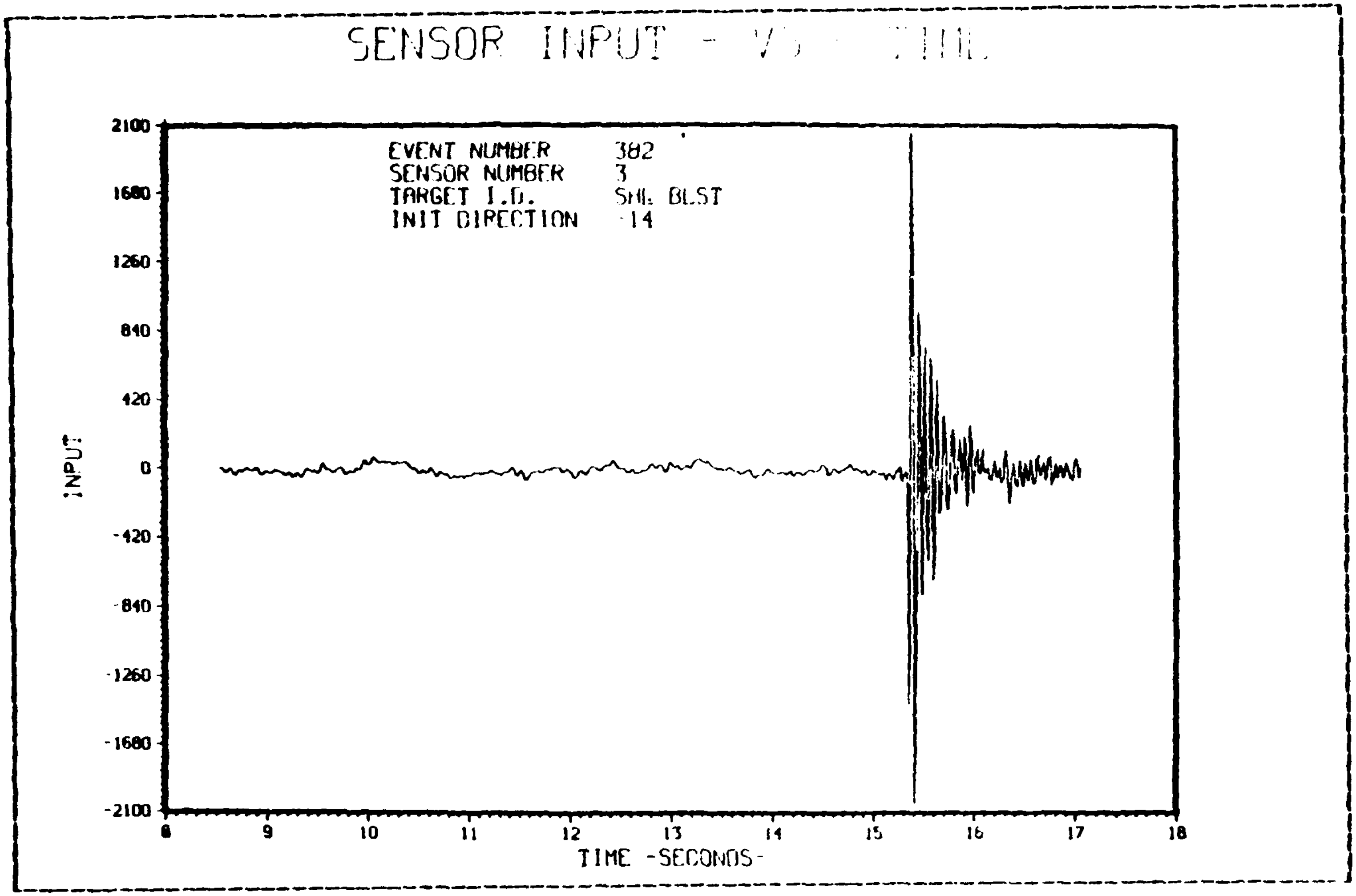

Figure 6.22 Amplitude Response for Event 382

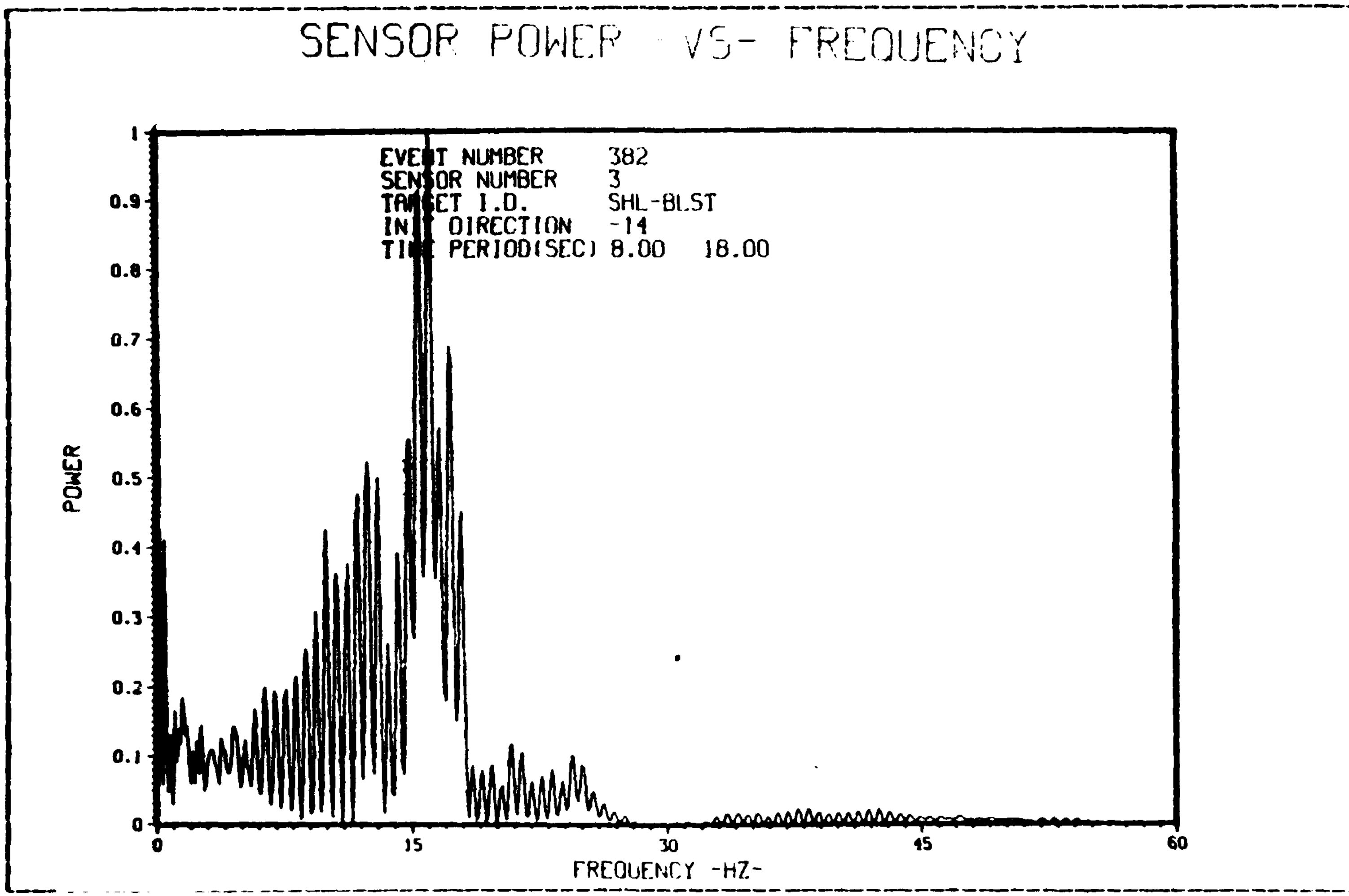

Figure 6.23 Frequency Response for Event 382

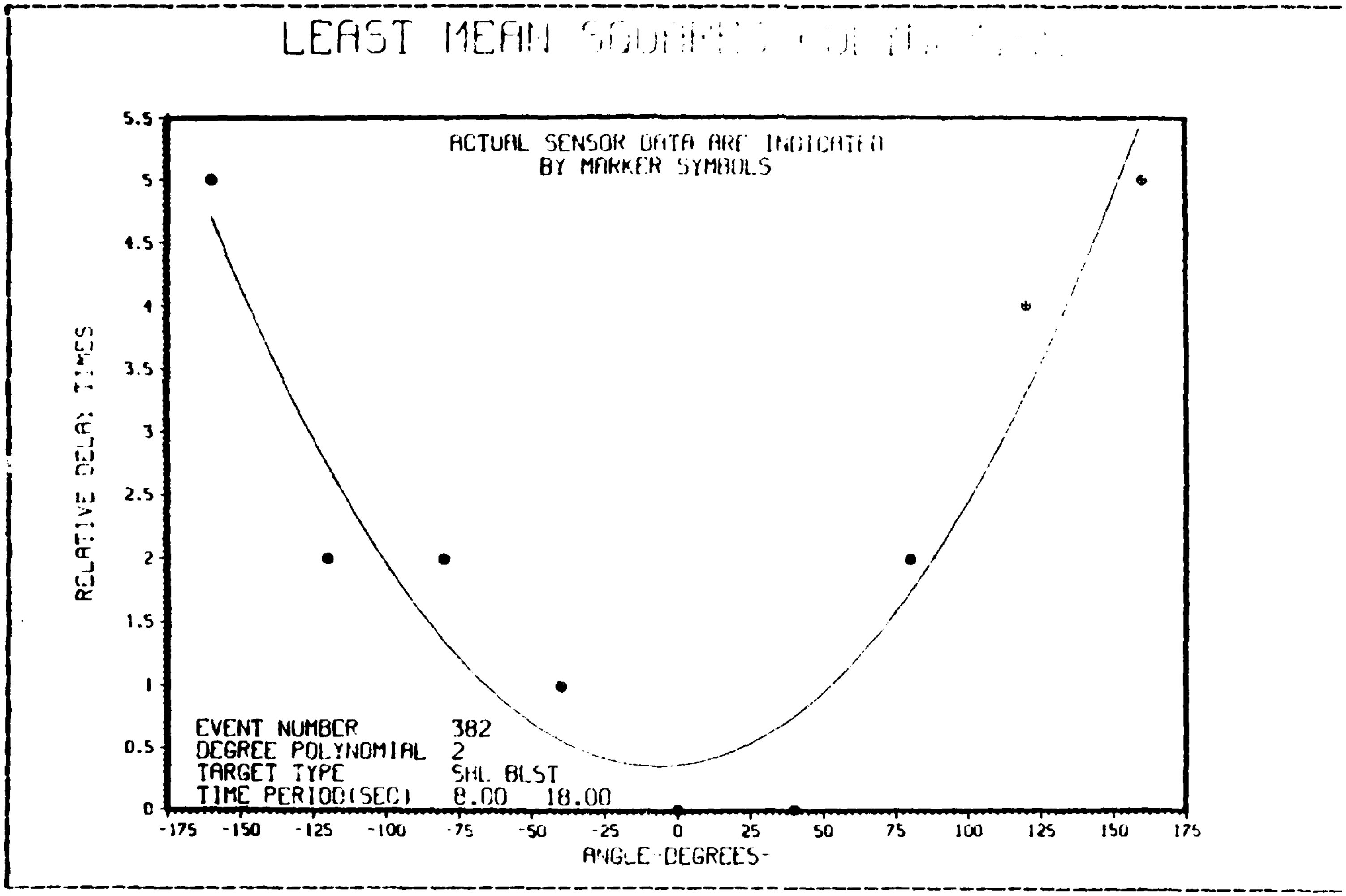

Figure 6.24 LMSP Matched Filter Direction for Event 382

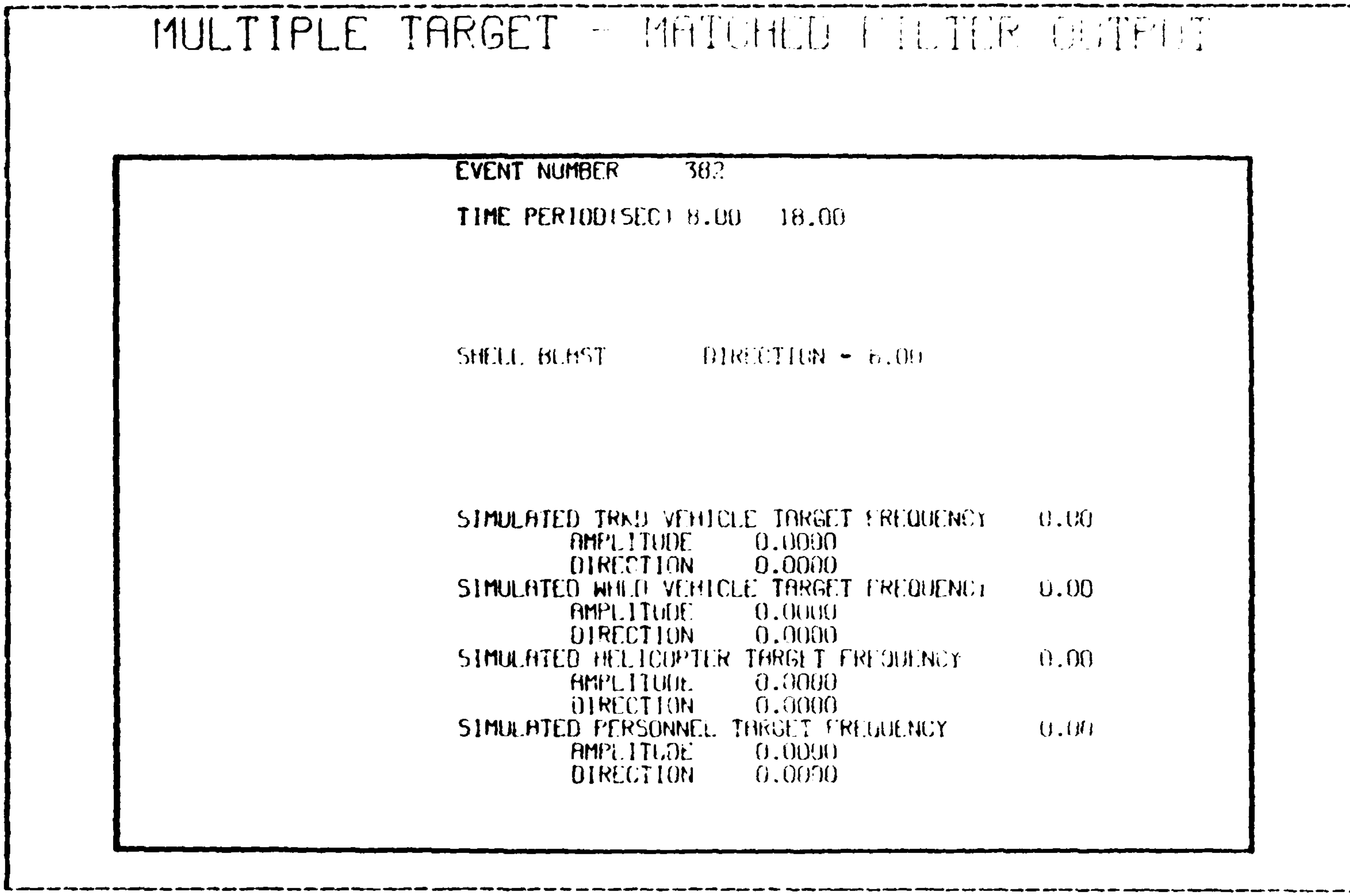

Figure 6.25 LMSP Multiple Target Direction Summary for Event 382

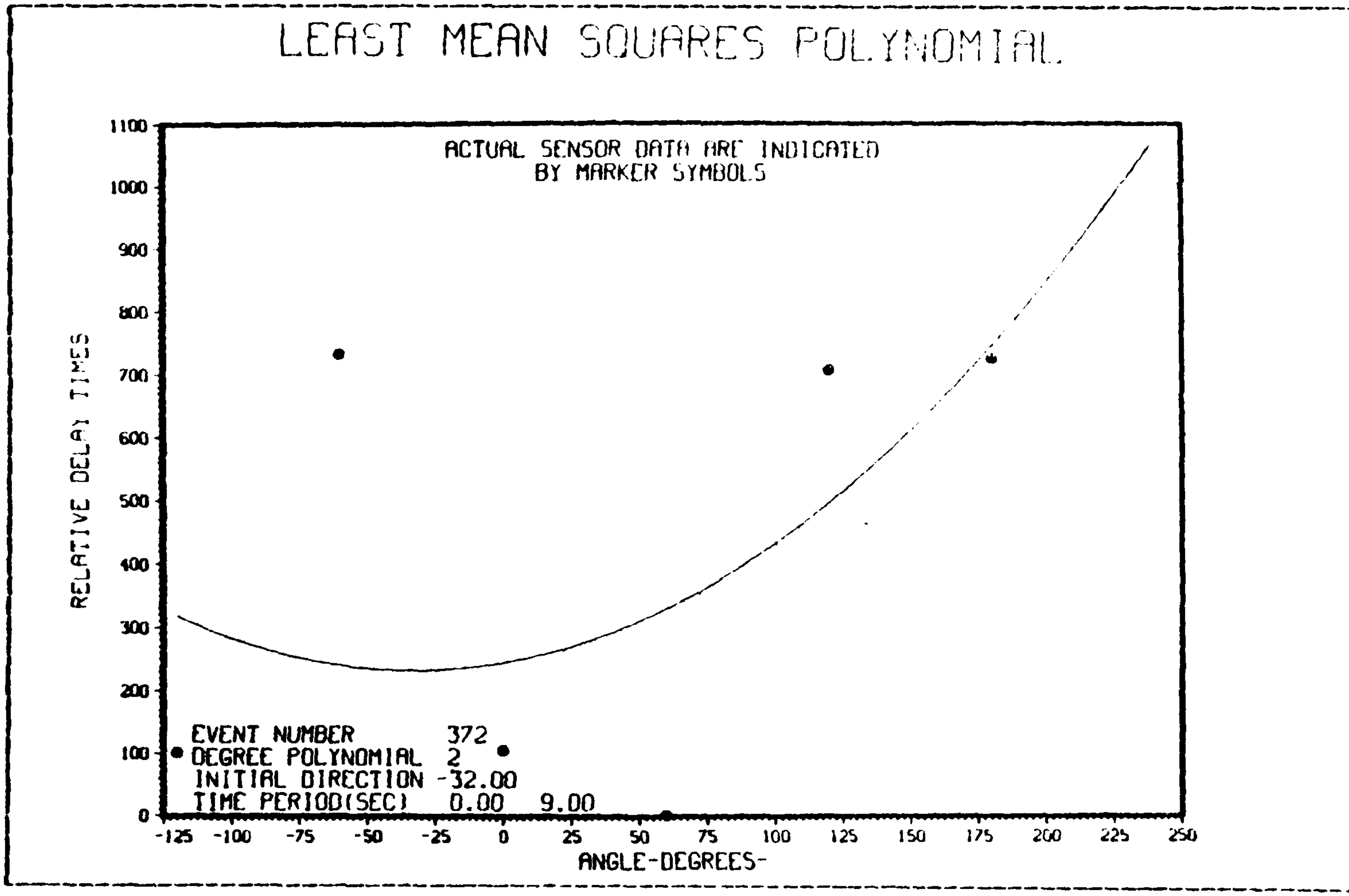

Figure 6.26 LMSP Initial Direction for Event 372

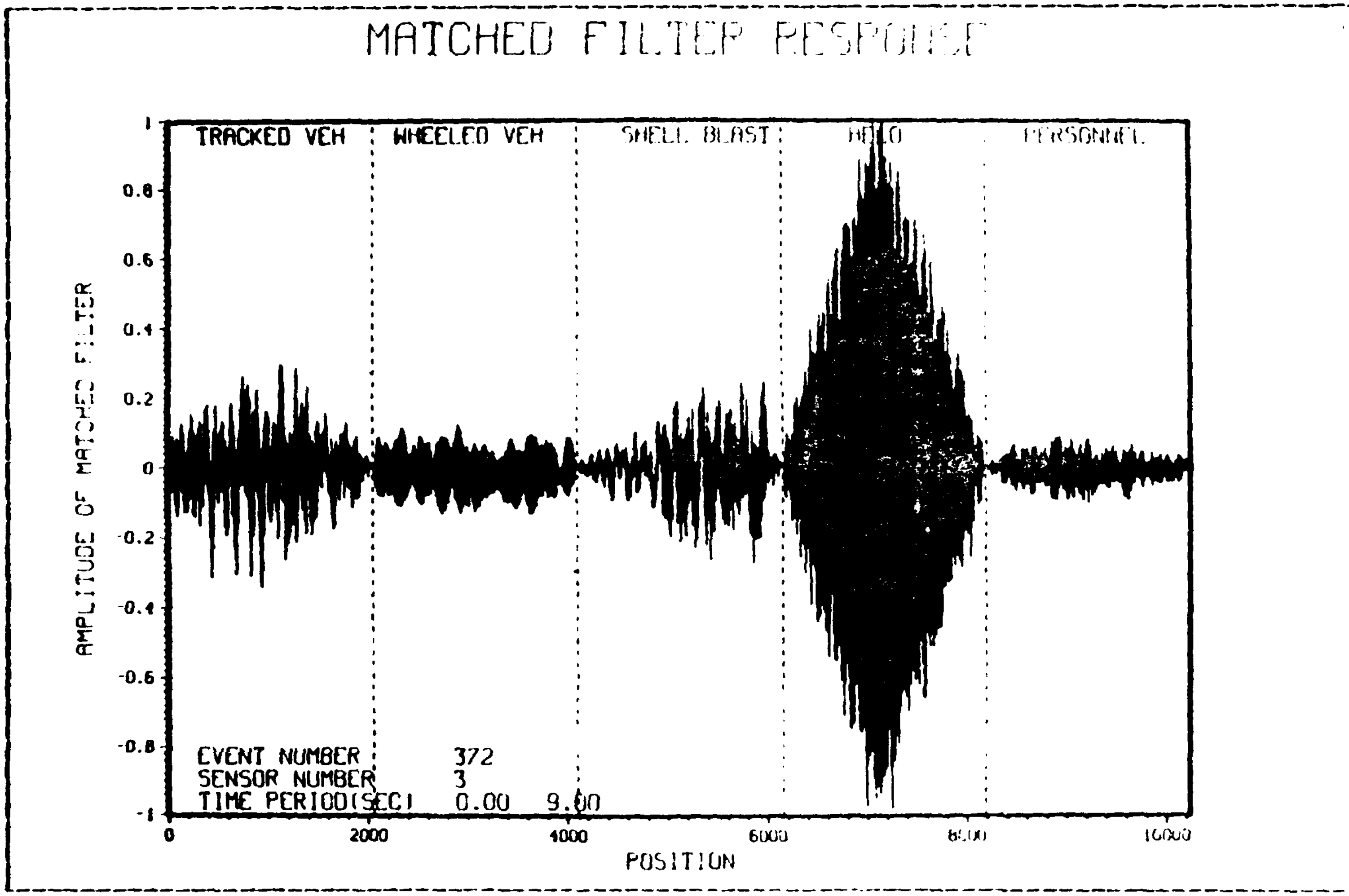

Figure 6.27 Matched Filter Response for Event 372

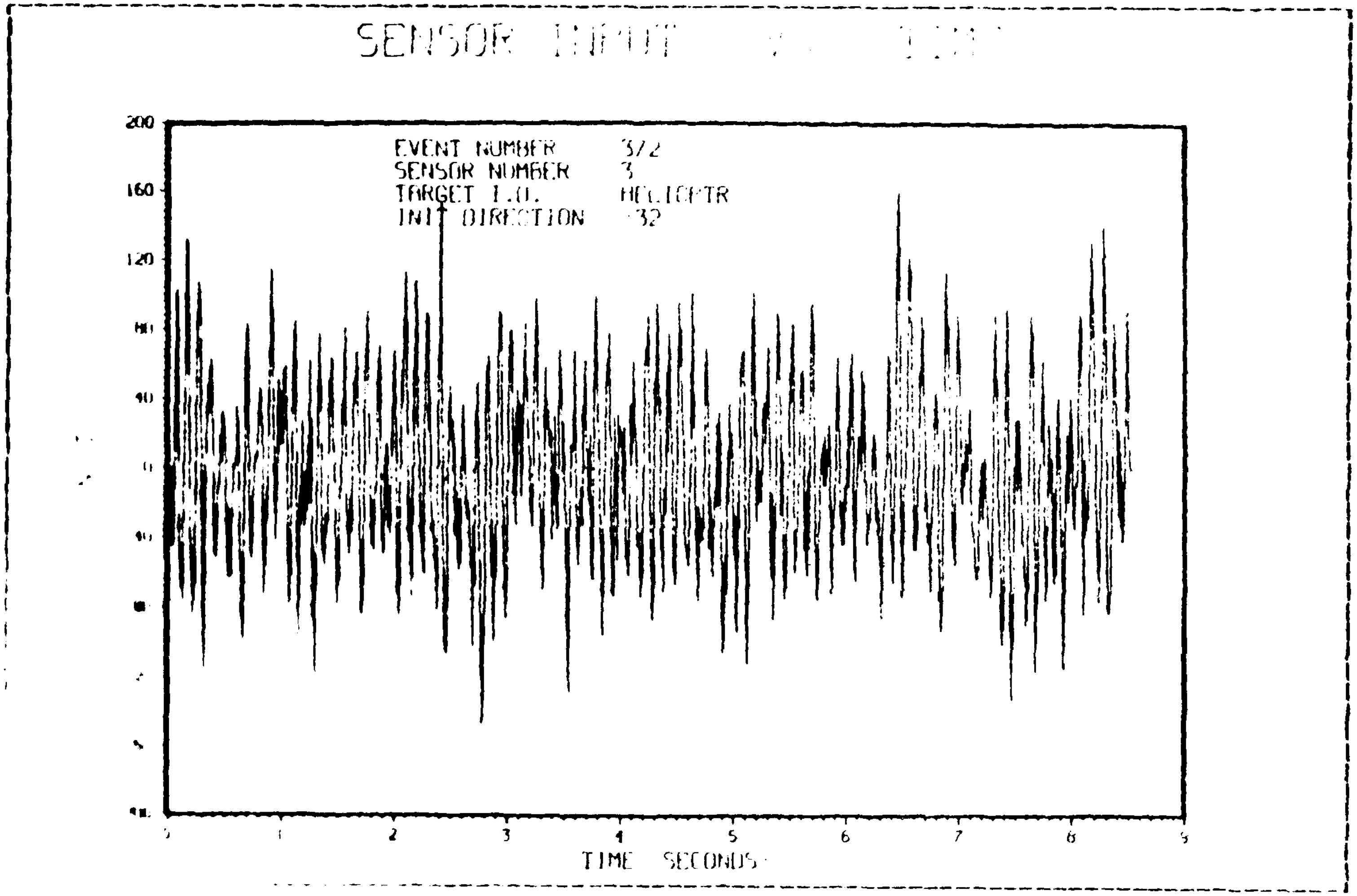

Figure 6.28 Amplitude Response for Event 372

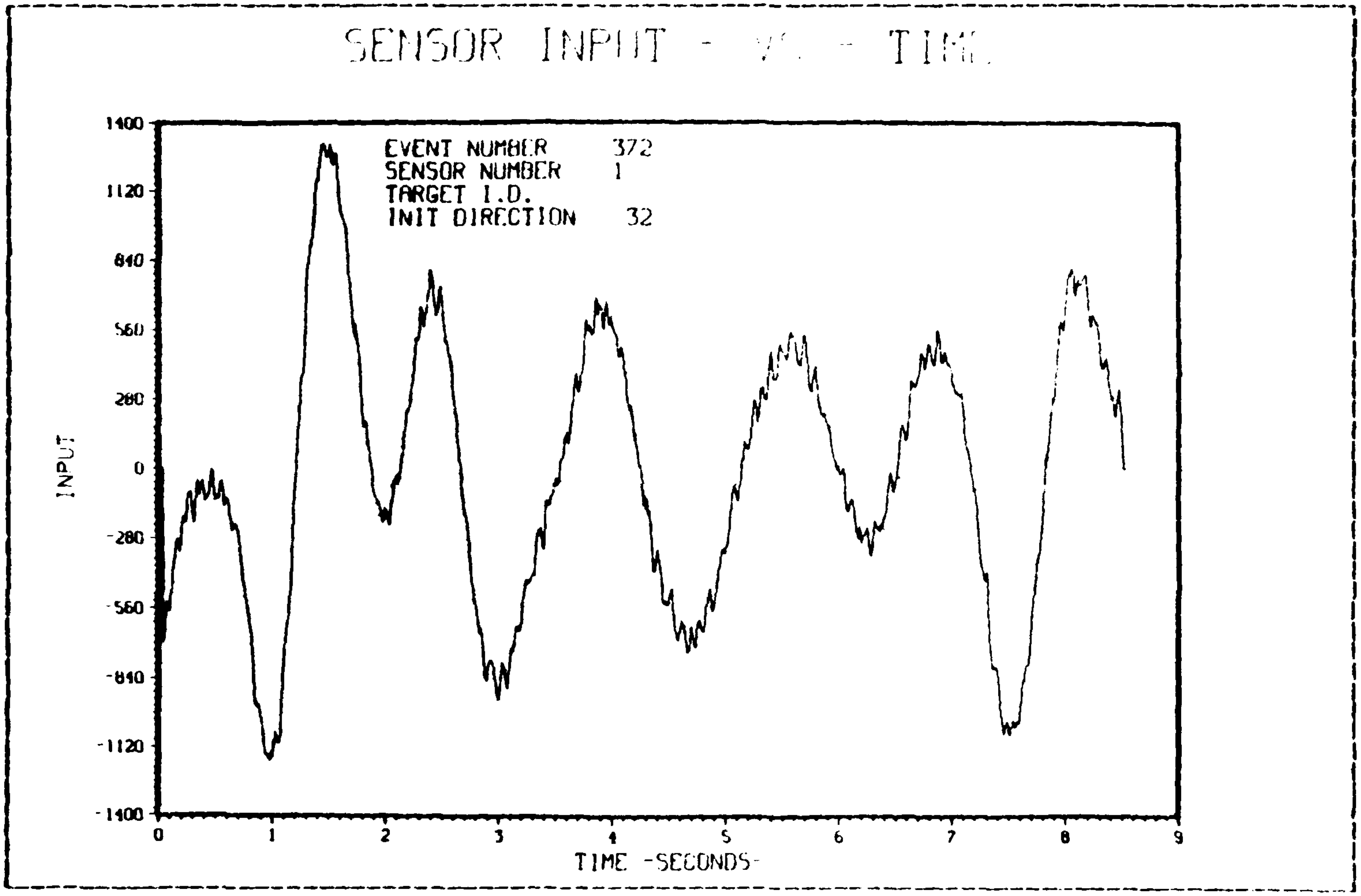

Figure 6.29 Amplitude Response of Malfunctioning Sensor for Event 372

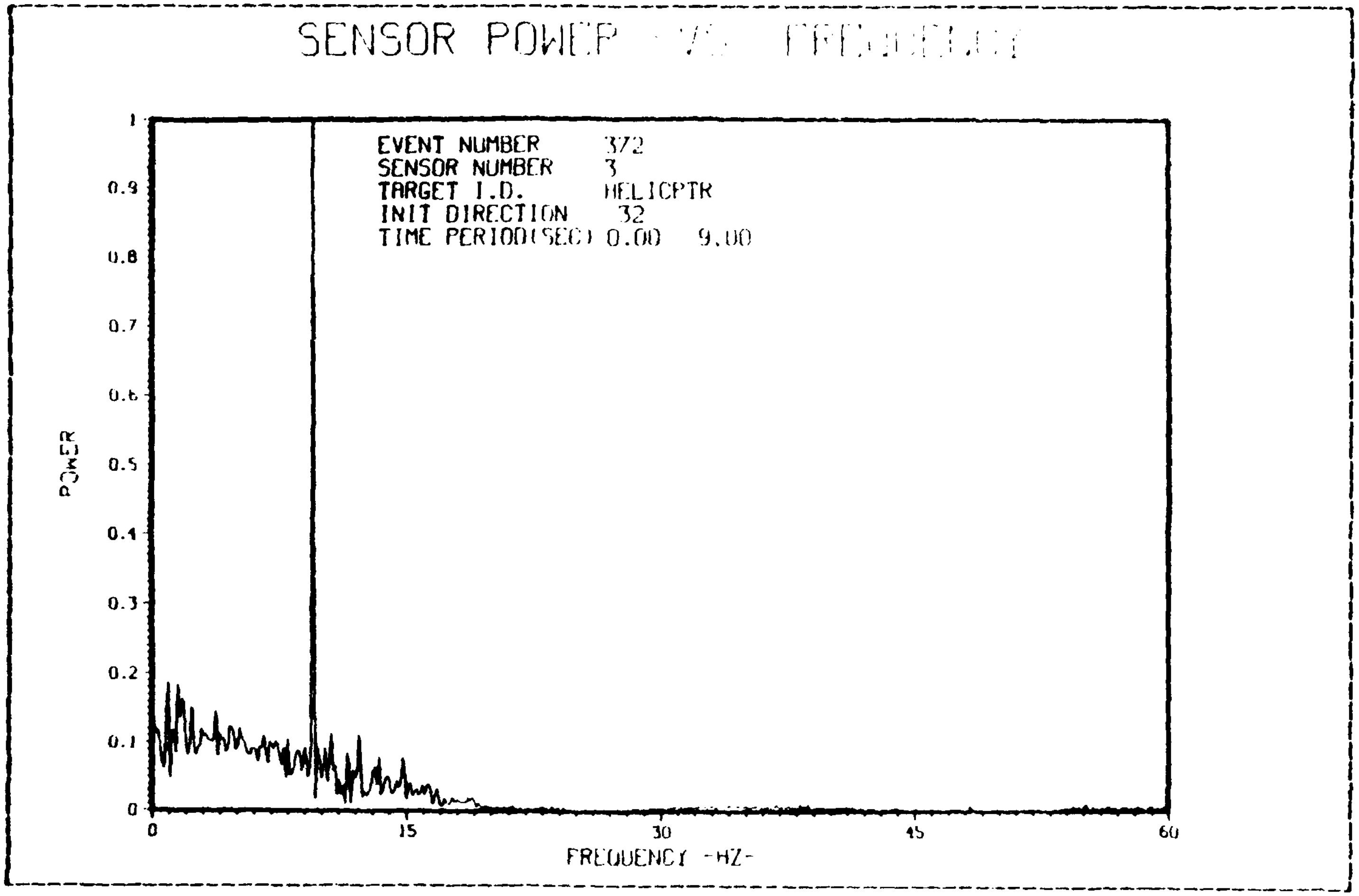

Figure 6.30 Frequency Response for Event 372

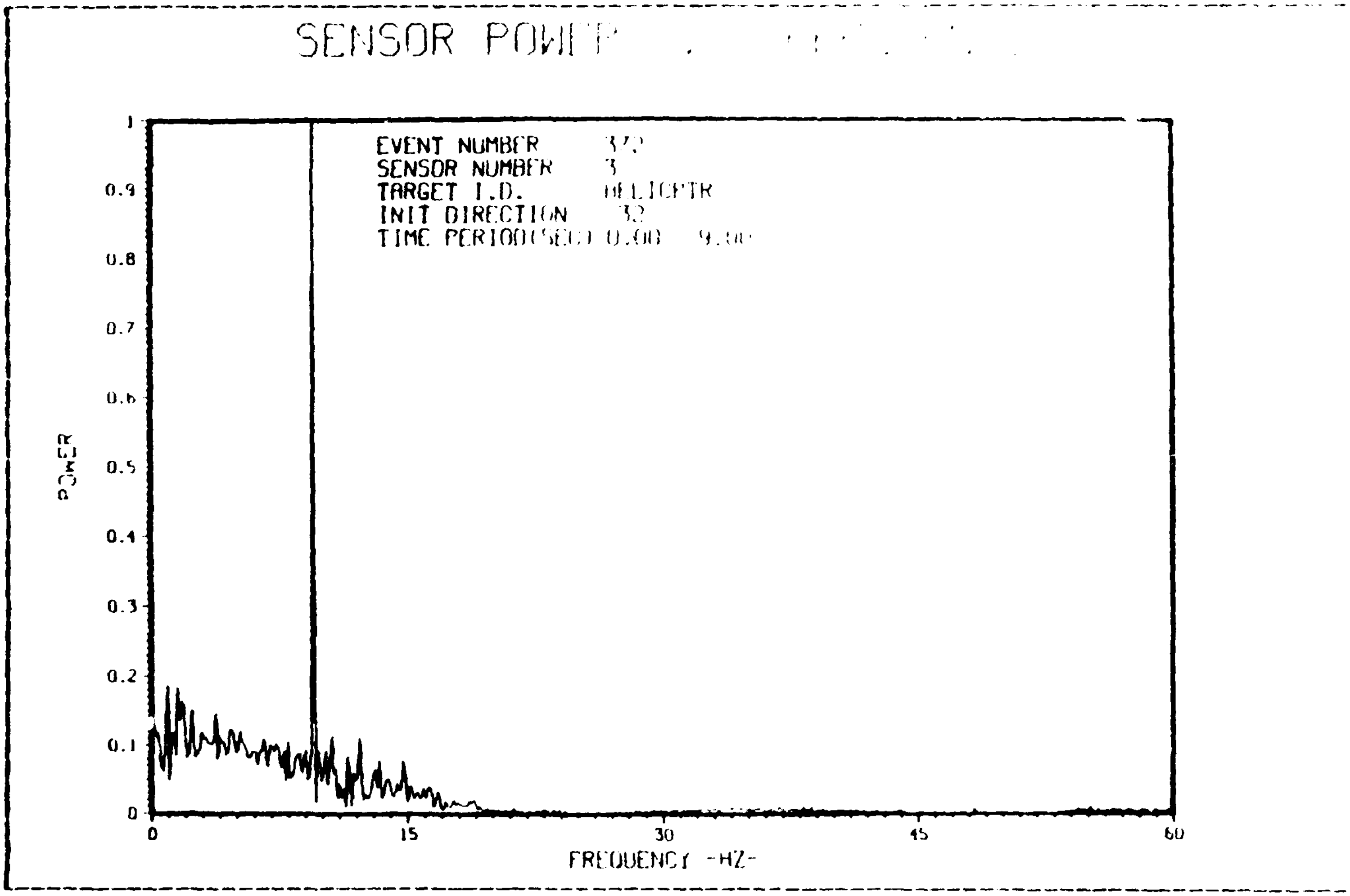

Figure 6.30 Frequency Response for Event 372

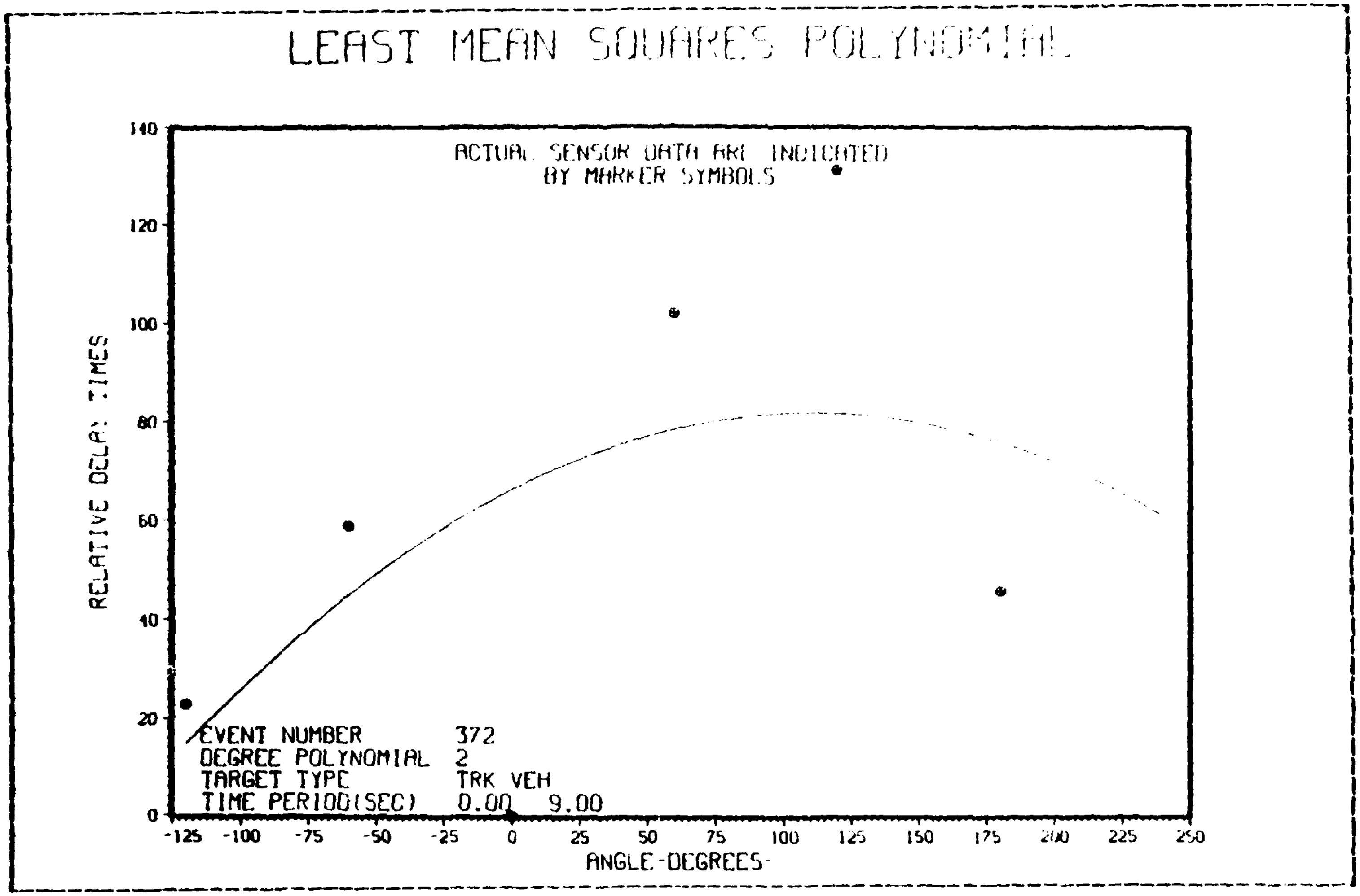

Figure 6.31 LMSP Matched Filter Direction for Event 372

MULTIPLE TARGET - MATCHED FILTER OUTPUT

EVENT NUMBER 372

TIME PERIOD(SEC) 0.00 9.00

TRACKED VEHICLE DIRECTION - 0.00

HELICOPTER DIRECTION - 0.00

SIMULATED TRKD VEHICLE TARGET FREQUENCY 0.00
AMPLITUDE 0.0000
DIRECTION 0.0000
SIMULATED WHLD VEHICLE TARGET FREQUENCY 0.00
AMPLITUDE 0.0000
DIRECTION 0.0000
SIMULATED HELICOPTER TARGET FREQUENCY 0.00
AMPLITUDE 0.0000
DIRECTION 0.0000
SIMULATED PERSONNEL TARGET FREQUENCY 0.00
AMPLITUDE 0.0000
DIRECTION 0.0000

Figure 6.32 LMSP Multiple Target Direction Summary for Event 372

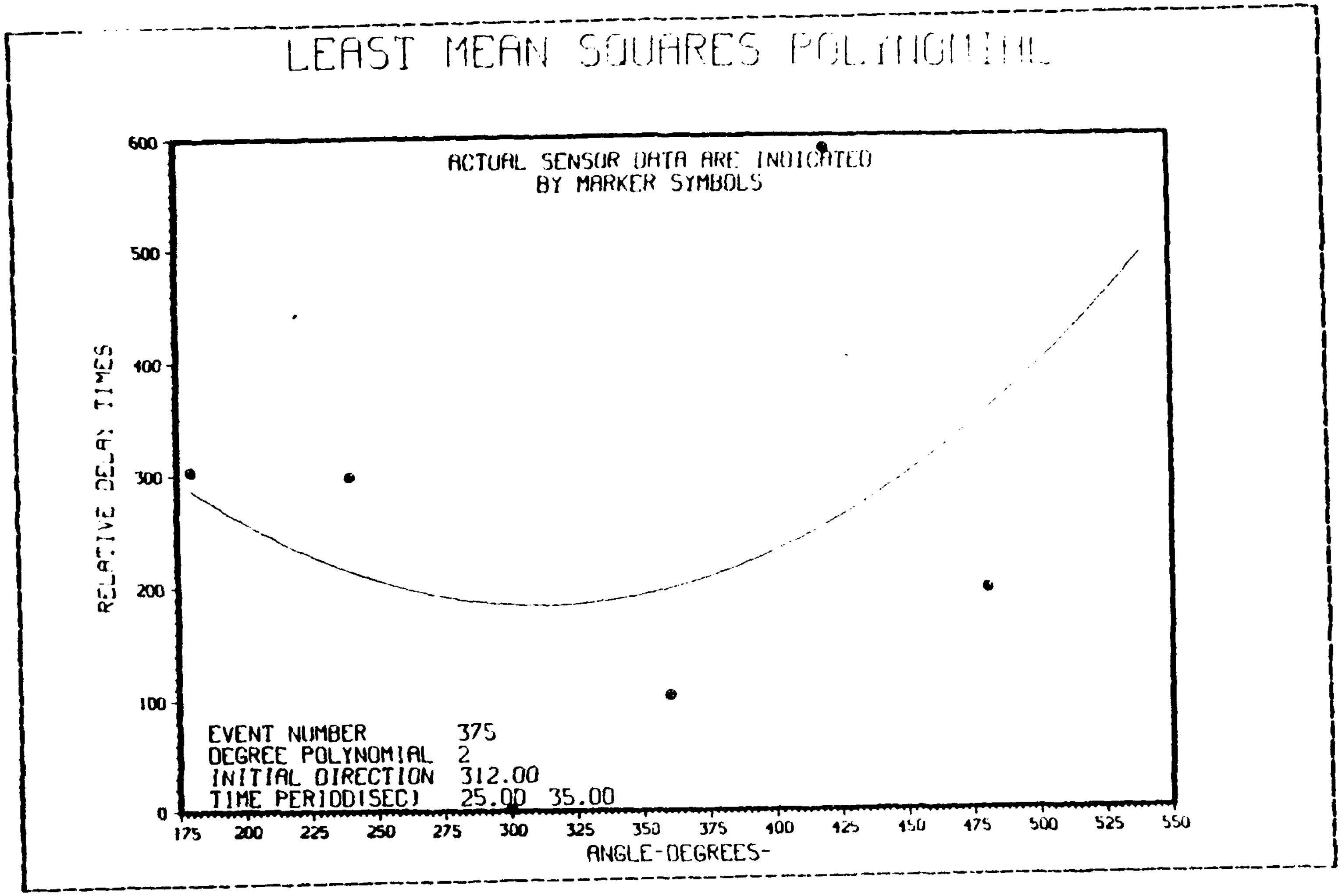

Figure 6.33 LMSP Initial Direction for Event 375

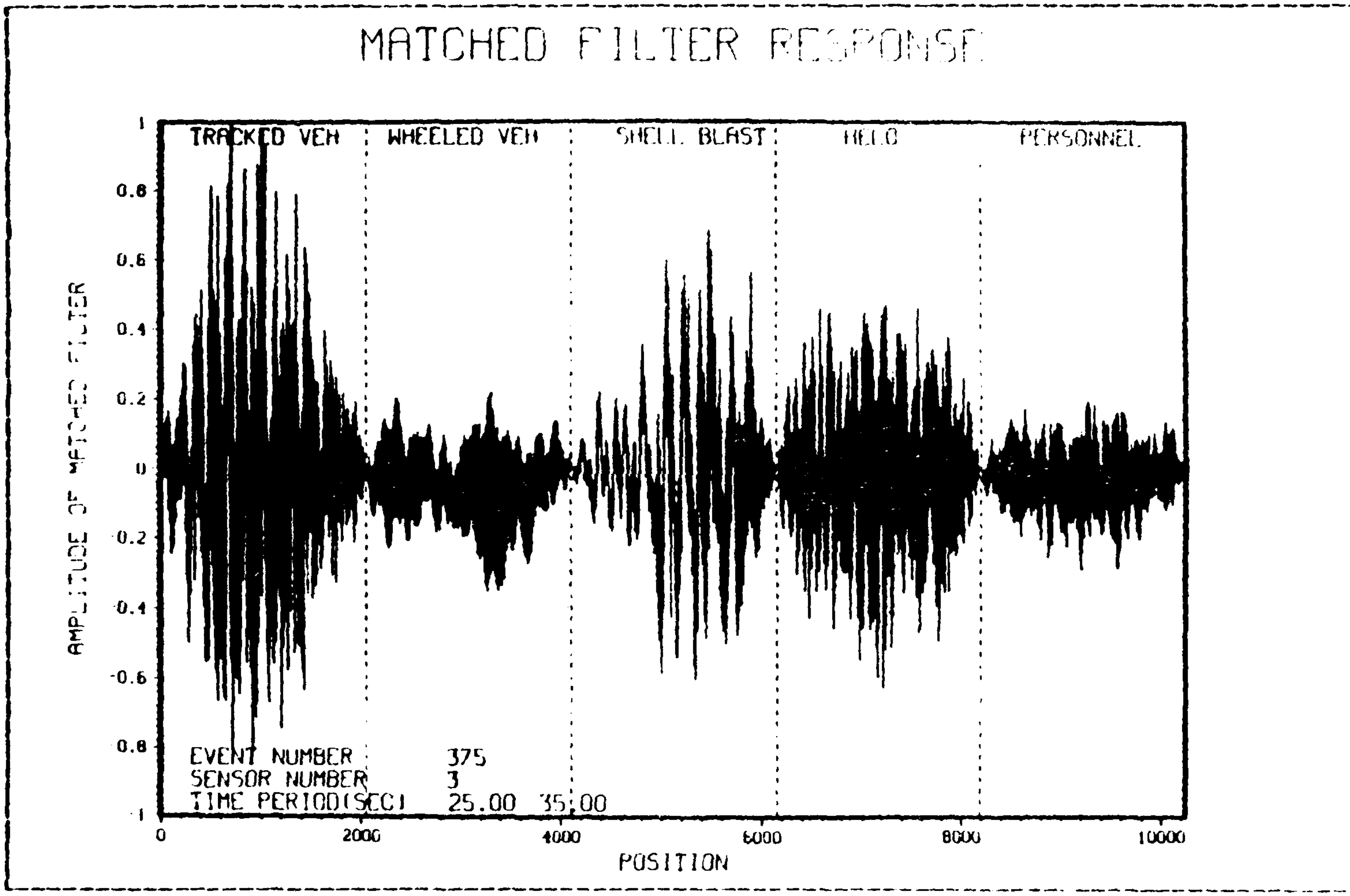

Figure 6.34 Matched Filter Response for Event 375

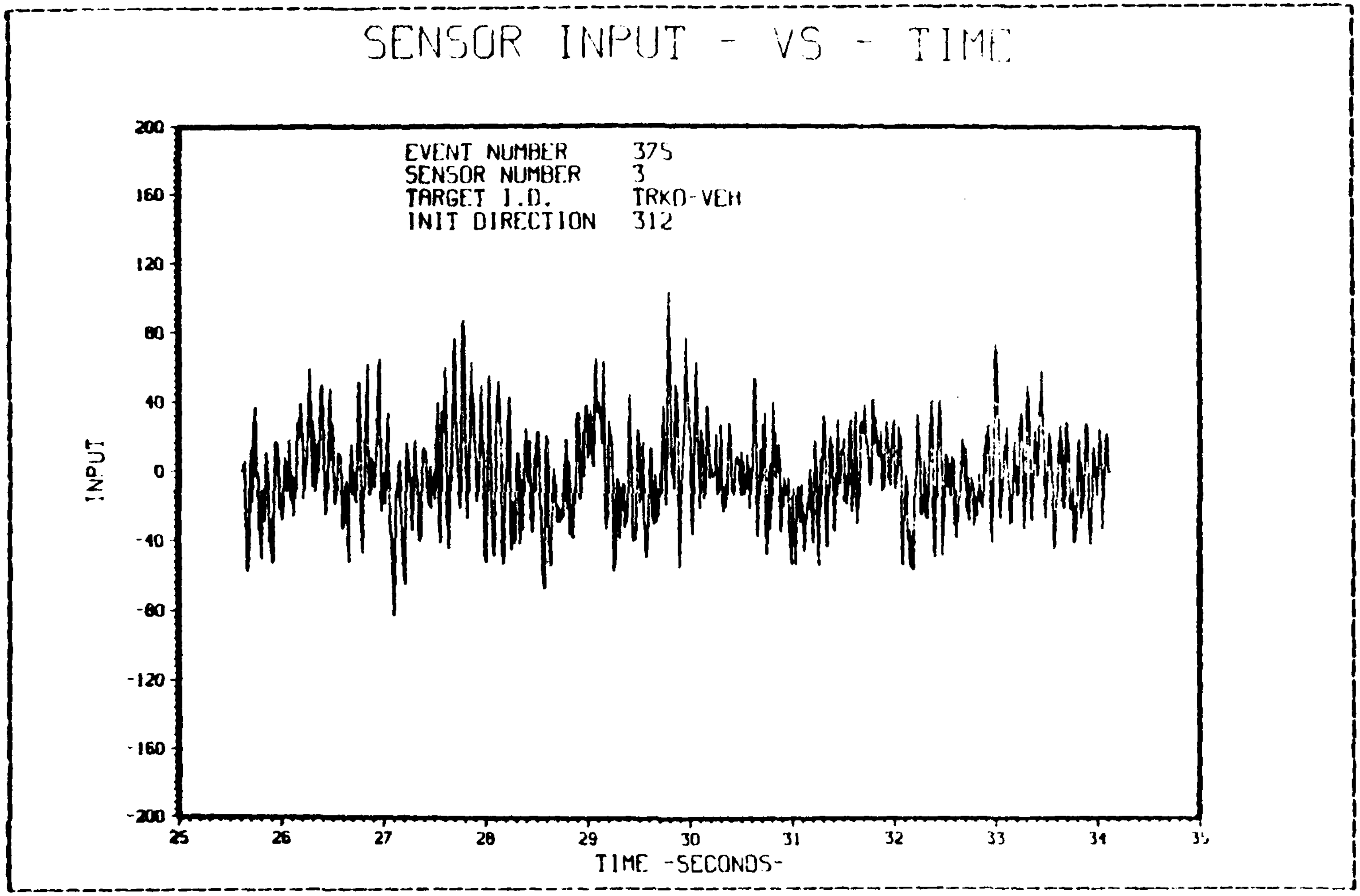

Figure 6.35 Amplitude Response for Event 375

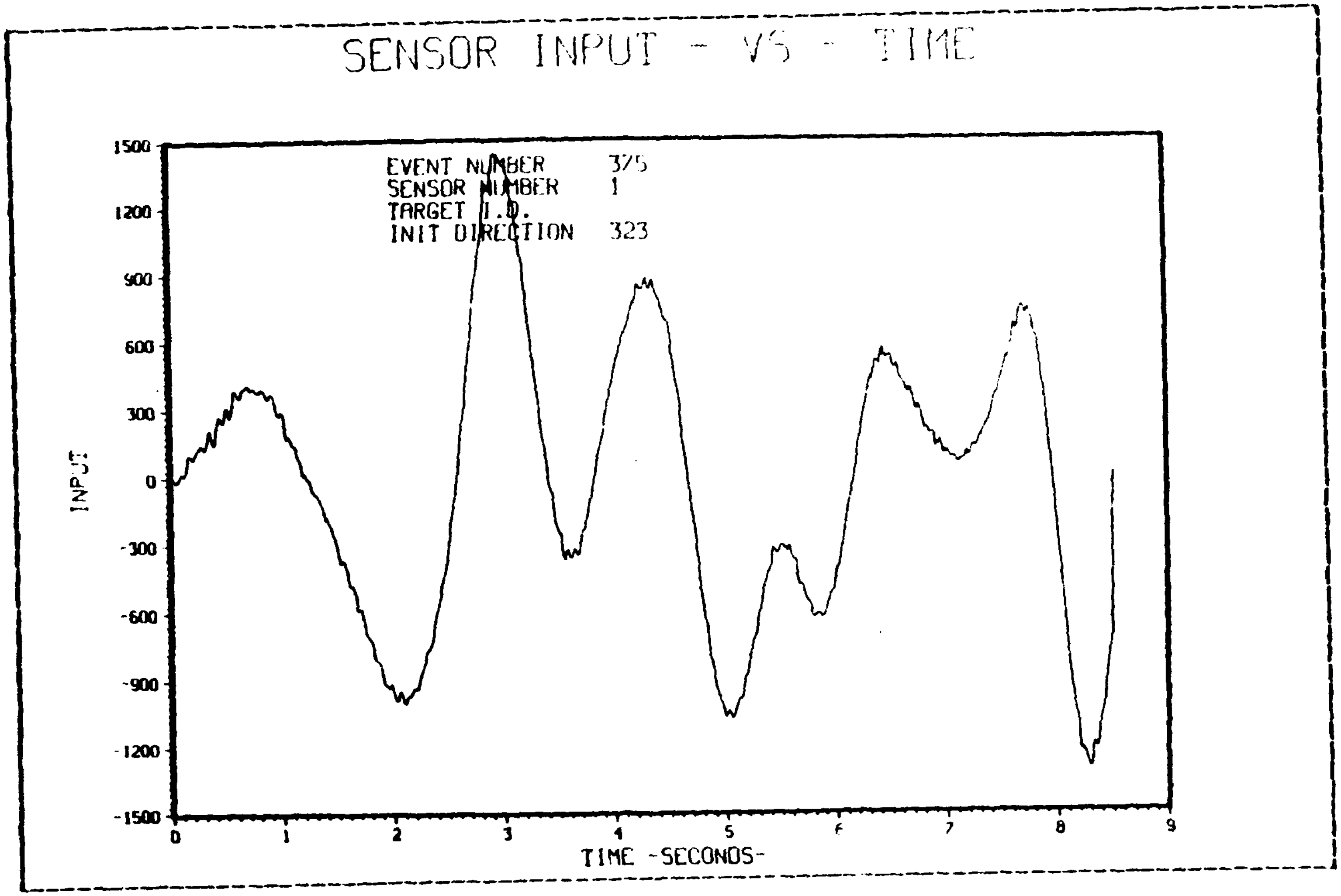

Figure 6.36 Amplitude Response of Malfunctioning Sensor for Event 375

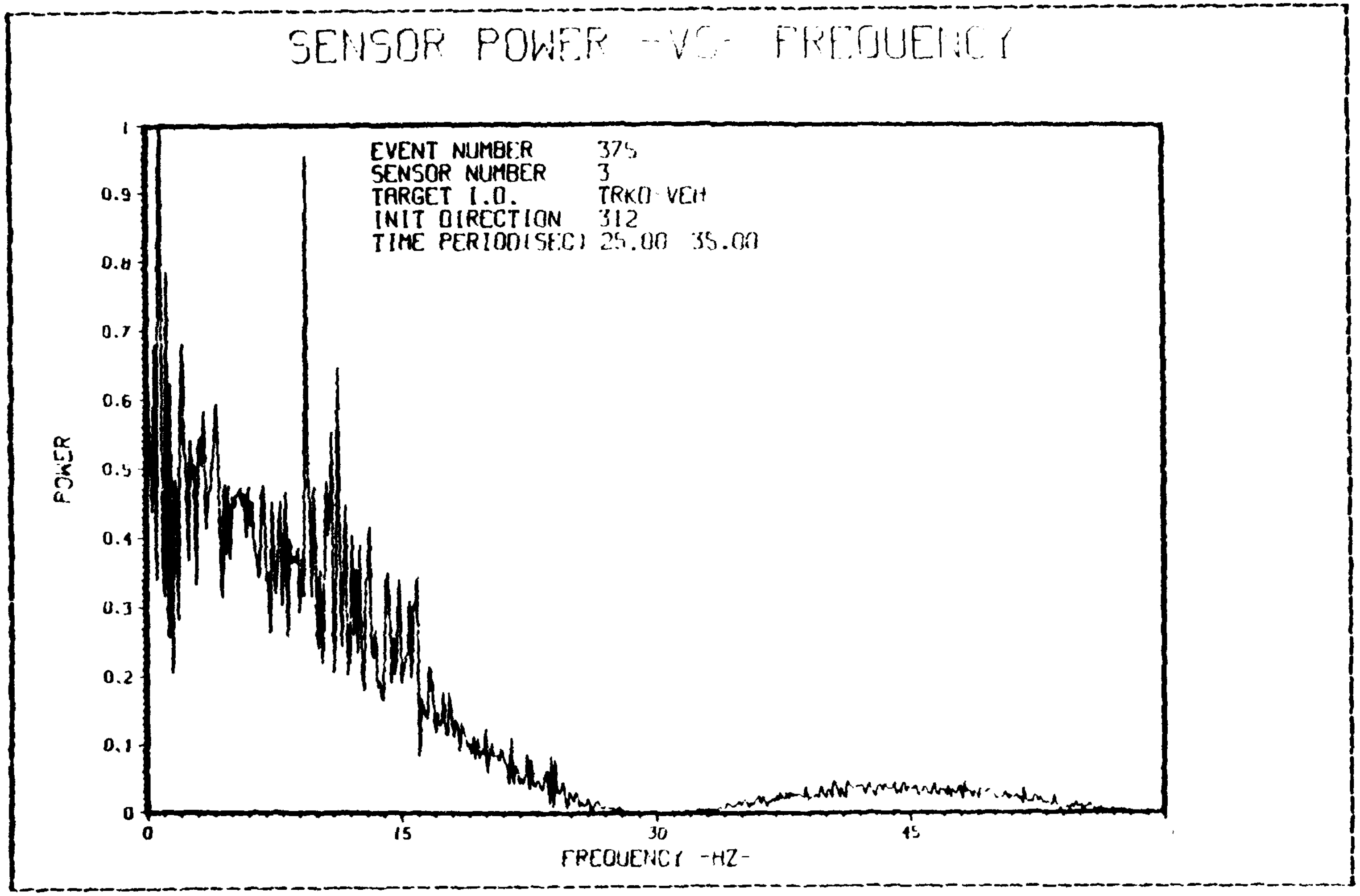

Figure 6.37 Frequency Response for Event 375

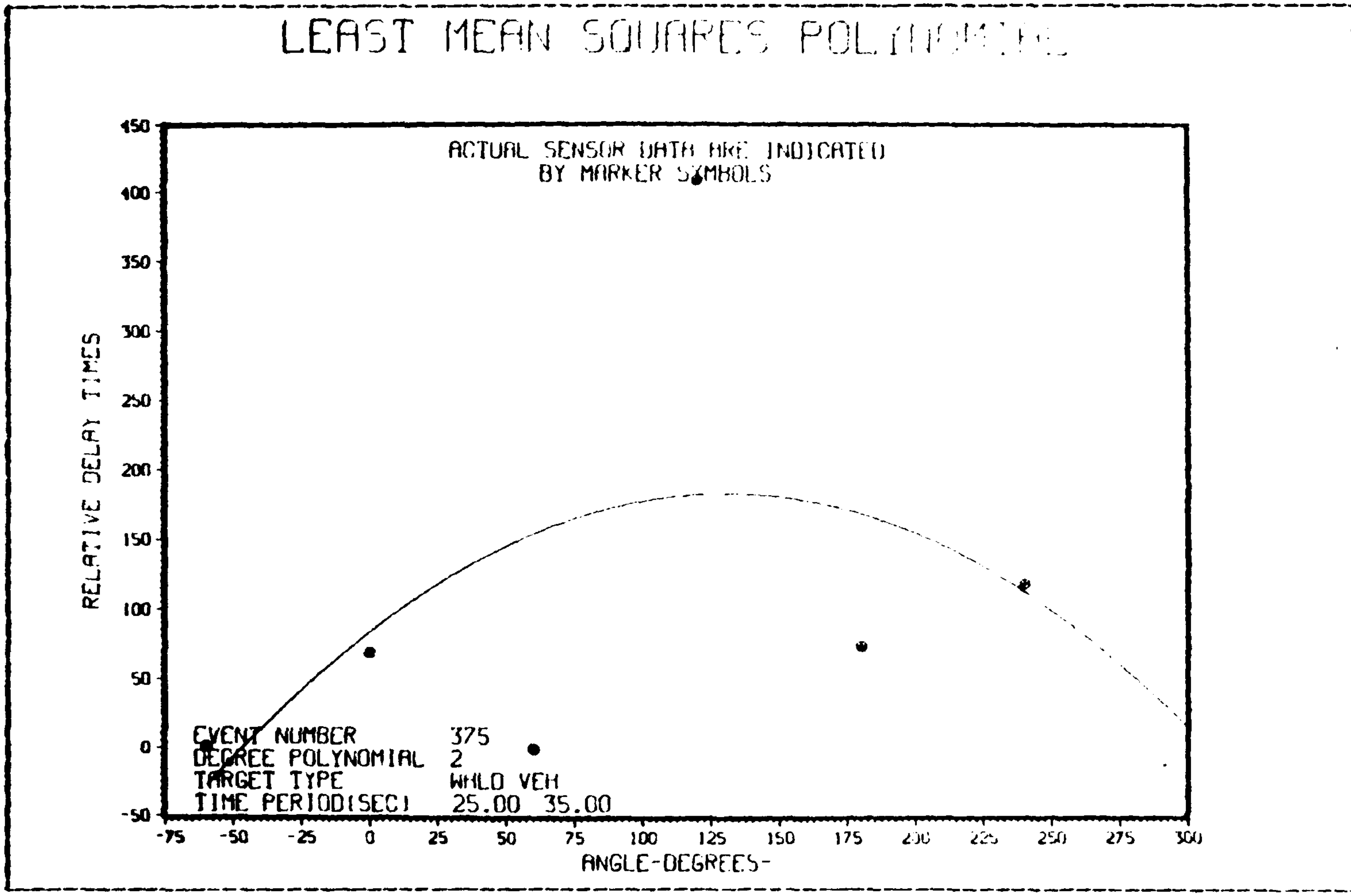

Figure 6.38 LMSP Matched Filter Direction for Event 375

```
MULTIPLE TARGET - MATCHED FILTER OUTPUT

EVENT NUMBER      375

TIME PERIOD(SEC) 25.00  35.00

TRACKED VEHICLE    DIRECTION - 0.00


SHELL BLAST        DIRECTION - 312.00

HELICOPTER         DIRECTION - 0.00



SIMULATED TRKD VEHICLE TARGET FREQUENCY    0.00
          AMPLITUDE      0.0000
          DIRECTION      0.0000
SIMULATED WHLD VEHICLE TARGET FREQUENCY    0.00
          AMPLITUDE      0.0000
          DIRECTION      0.0000
SIMULATED HELICOPTER TARGET FREQUENCY      0.00
          AMPLITUDE      0.0000
          DIRECTION      0.0000
SIMULATED PERSONNEL TARGET FREQUENCY       0.00
          AMPLITUDE      0.0000
          DIRECTION      0.0000
```

Figure 6.39 LMSP Multiple Target Direction Summary for Event 375

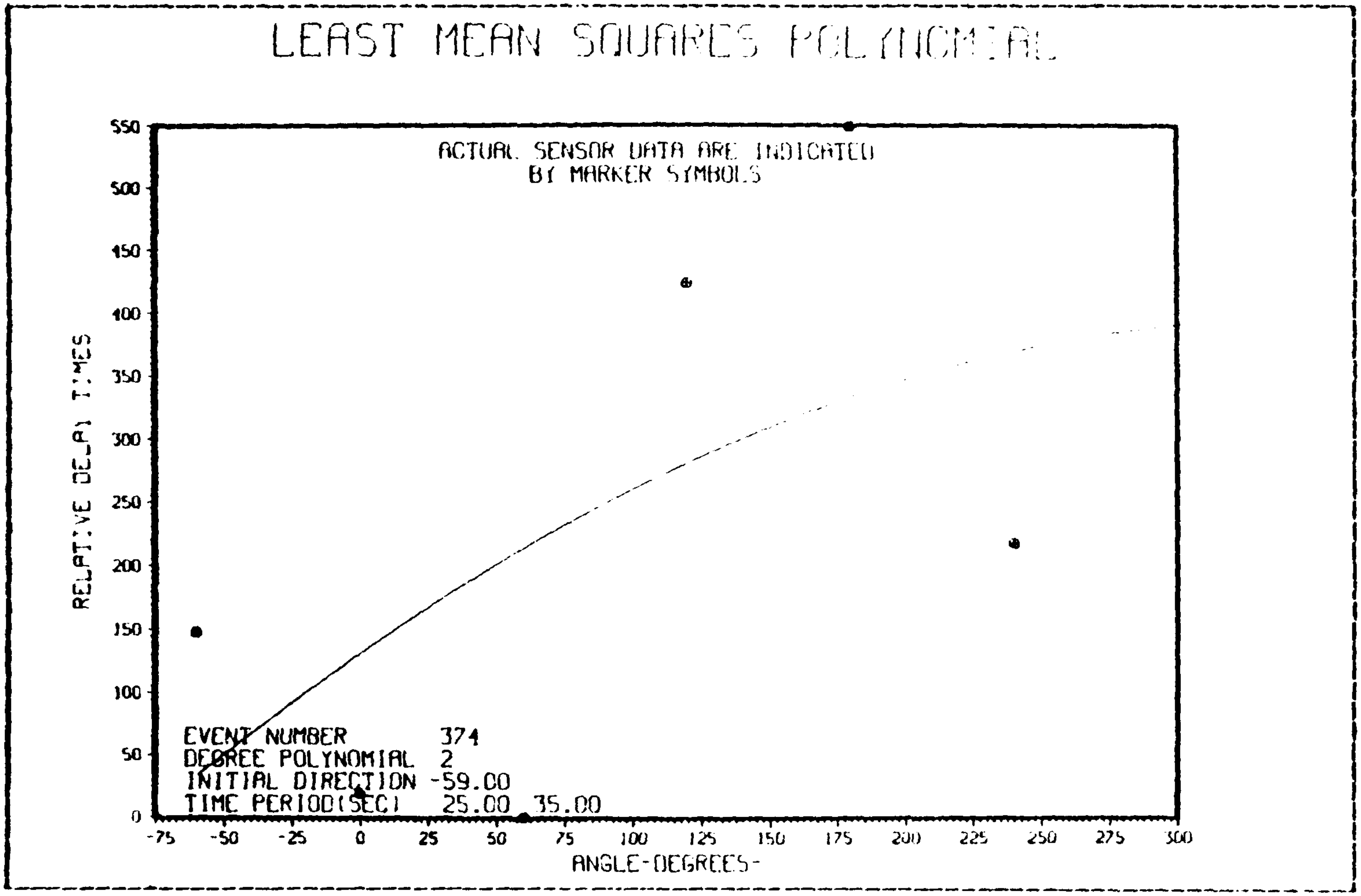

Figure 6.40 LMSP Initial Direction for Event 374

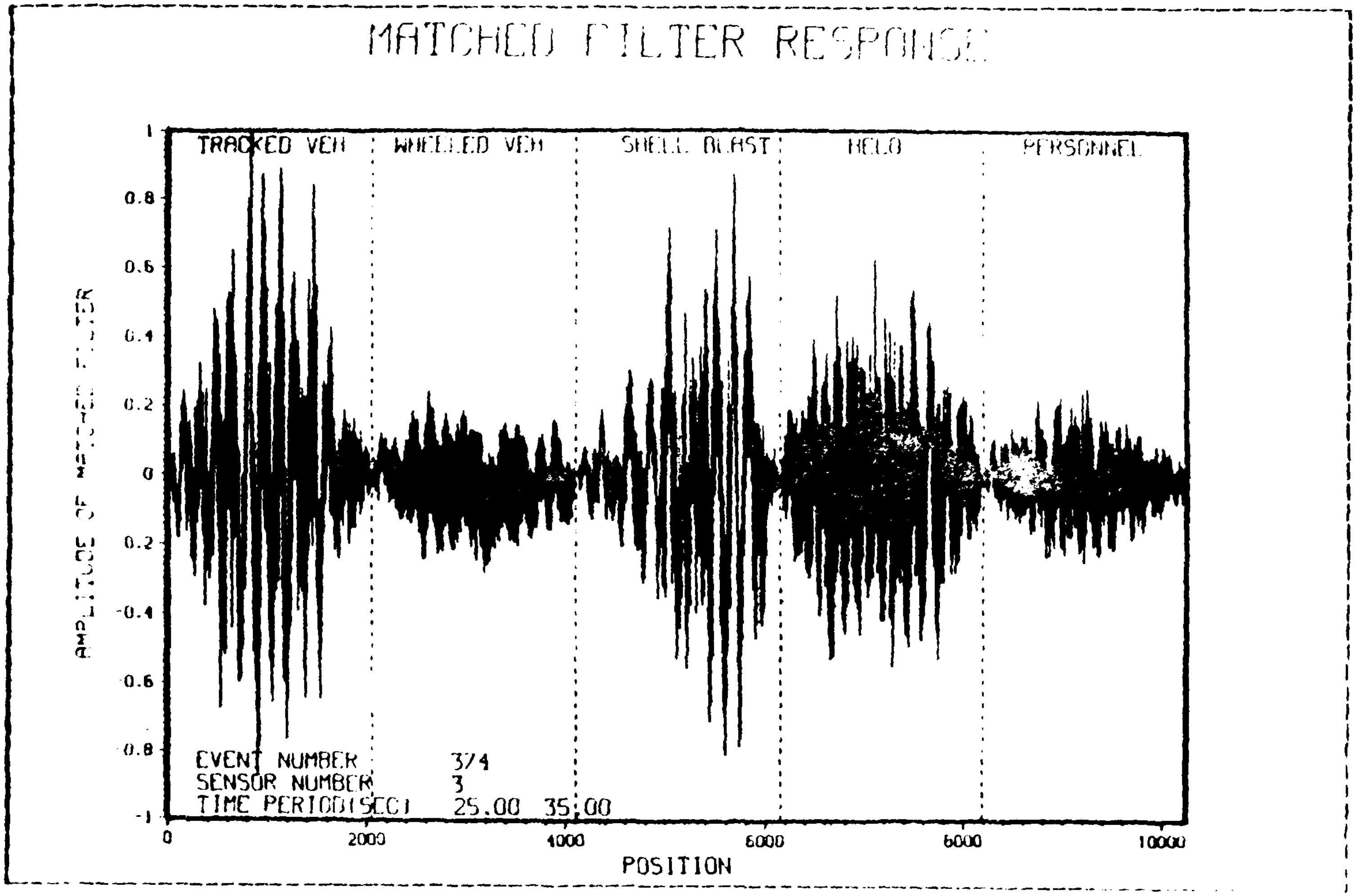

Figure 6.41 Matched Filter Response for Event 374

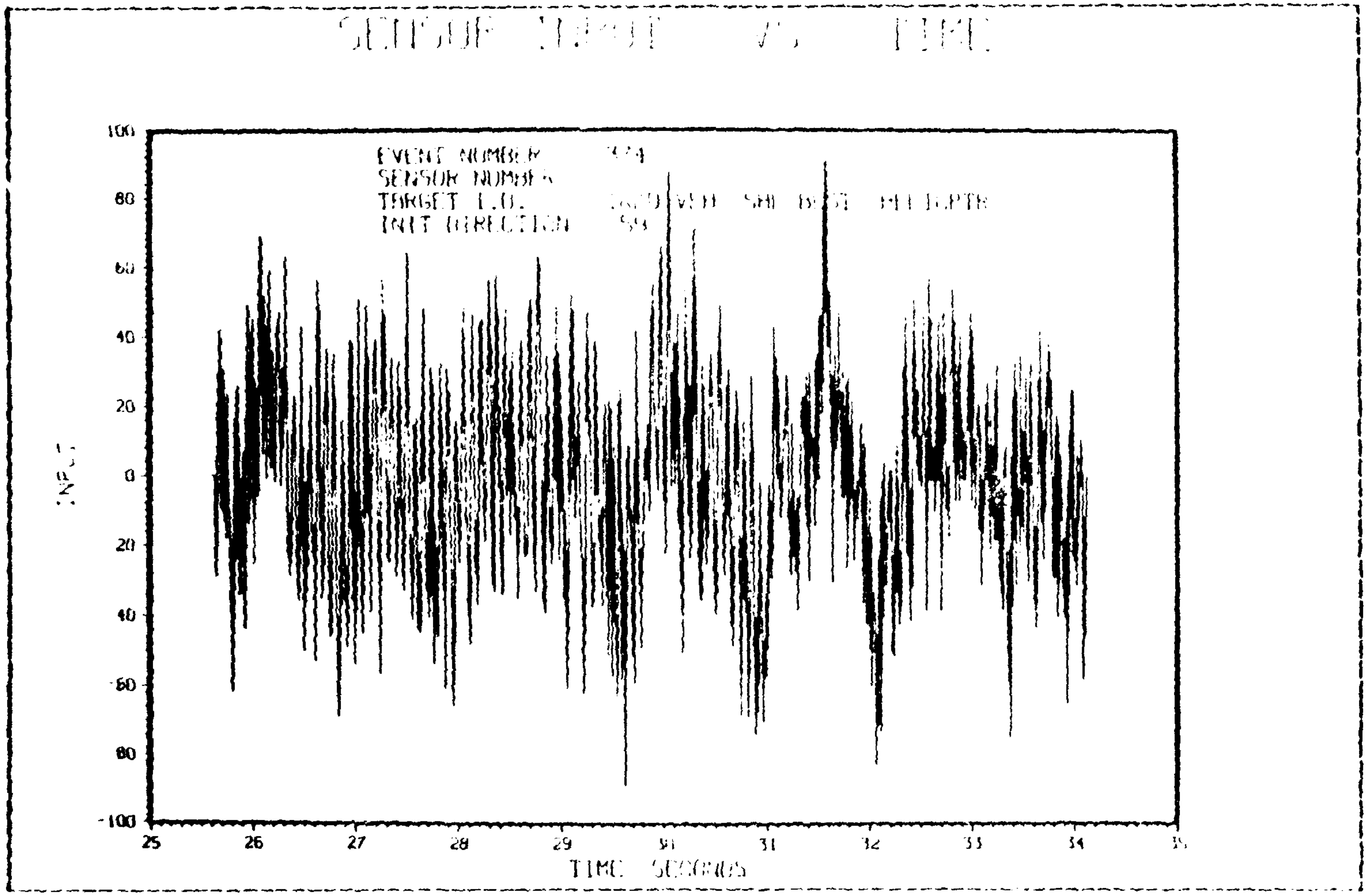

Figure 6.42 Amplitude Response for Event 374

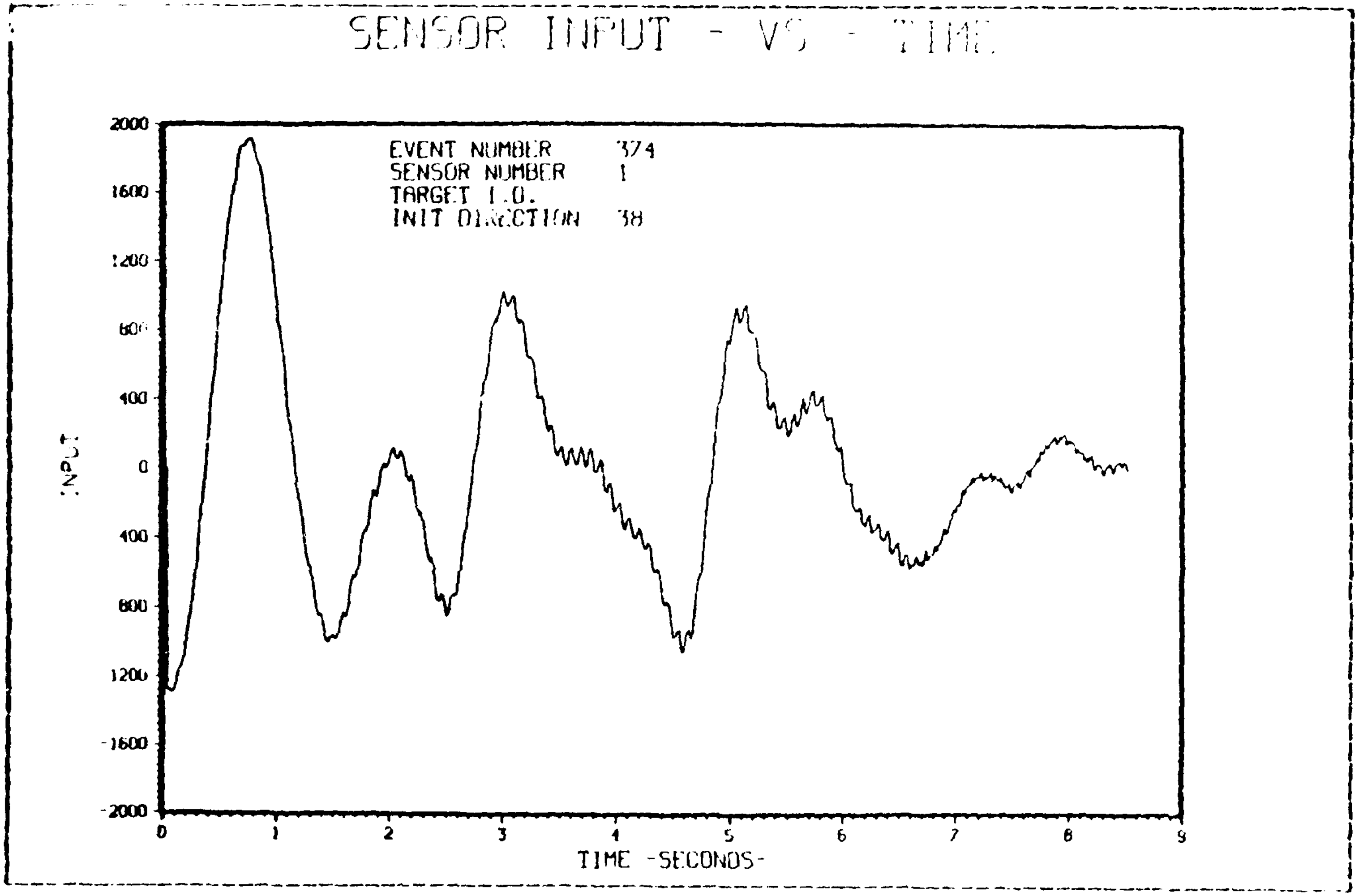

Figure 6.43 Amplitude Response of Malfunctioning Sensor for Event 374

AD-A138 914 MULTIPLE TARGET IDENTIFICATION AND DIRECTION FINDING USING MATCHED FILTERING TECHNIQUES(U) NAVAL POSTGRADUATE SCHOOL MONTEREY CA J L JOHNSTON DEC 83

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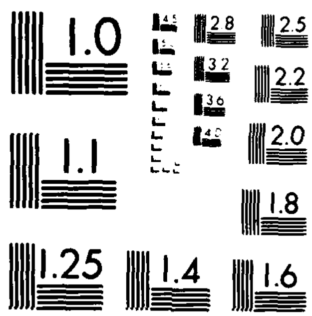

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

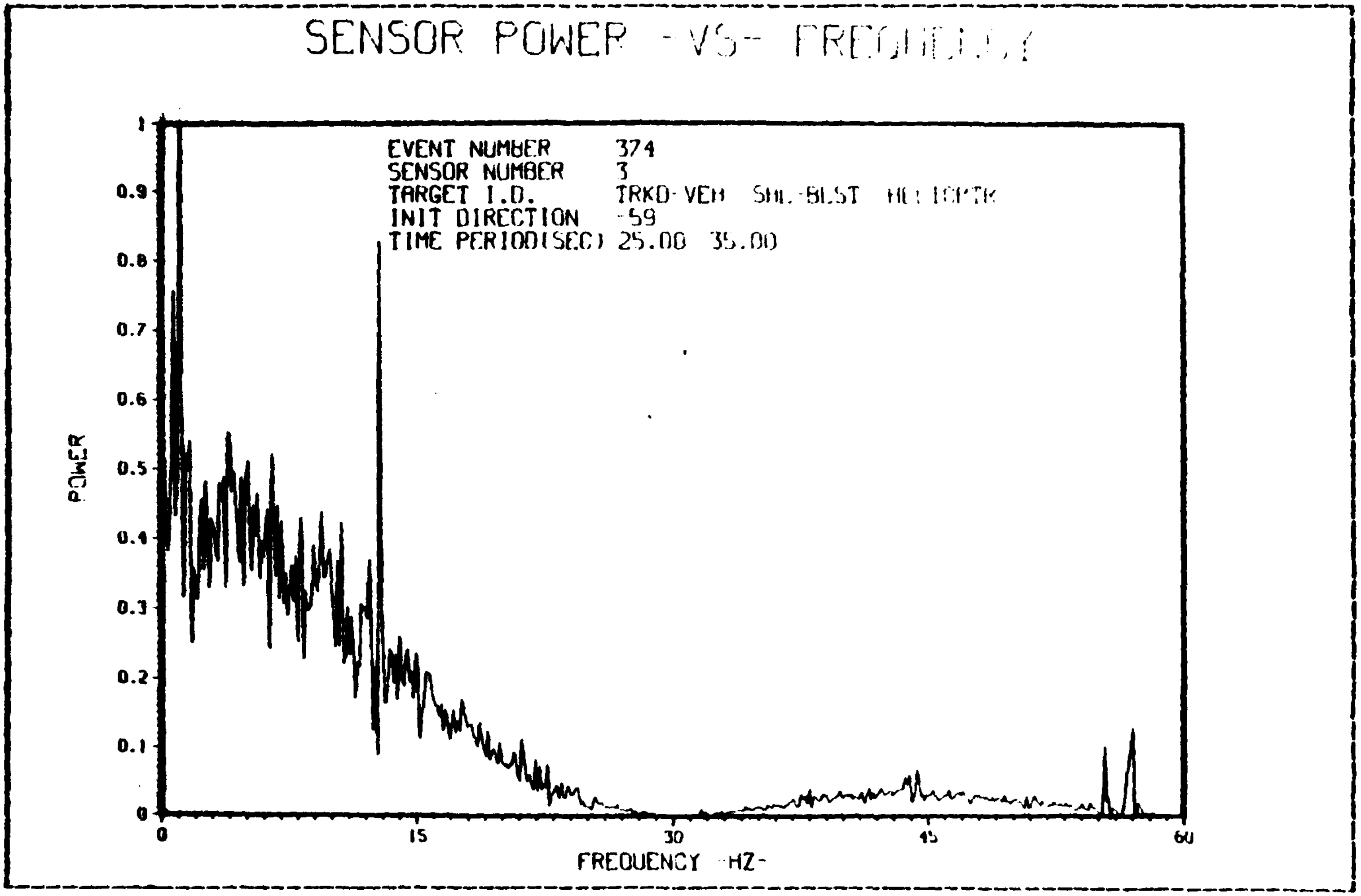

Figure 6.44 Frequency Response for Event 374

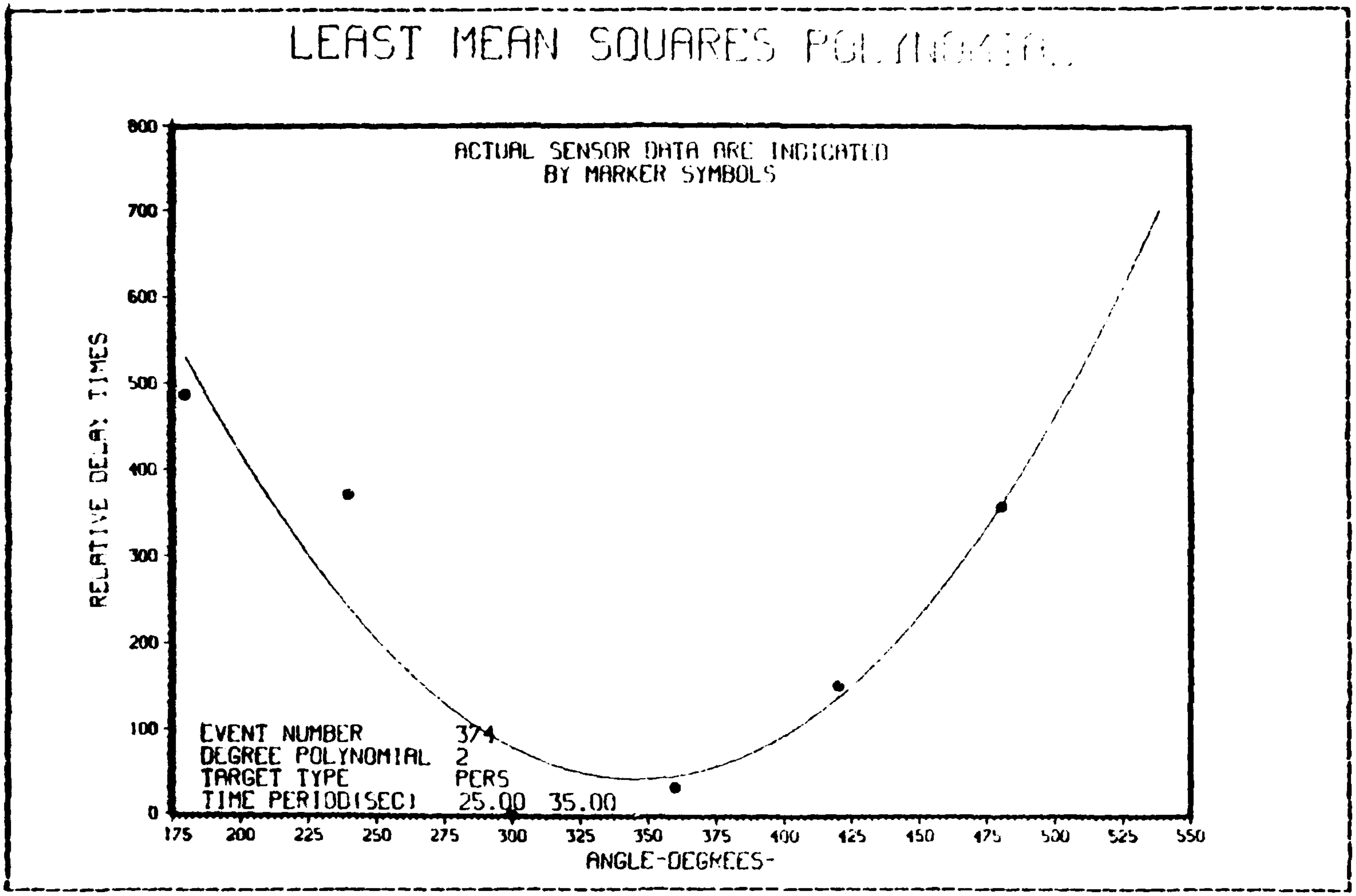

Figure 6.45 LMSP Matched Filter Direction for Event 374

MULTIPLE TARGET - MATCHED FILTER OUTPUT

```
EVENT NUMBER     374

TIME PERIOD(SEC) 25.00  35.00

TRACKED VEHICLE    DIRECTION - 59.00


SHELL BLAST        DIRECTION - 59.00


PERSONNEL          DIRECTION - 347.00


SIMULATED TRKD VEHICLE TARGET FREQUENCY    0.00
          AMPLITUDE     0.0000
          DIRECTION     0.0000
SIMULATED WHLD VEHICLE TARGET FREQUENCY    0.00
          AMPLITUDE     0.0000
          DIRECTION     0.0000
SIMULATED HELICOPTER TARGET FREQUENCY      0.00
          AMPLITUDE     0.0000
          DIRECTION     0.0000
SIMULATED PERSONNEL TARGET FREQUENCY       0.00
          AMPLITUDE     0.0000
          DIRECTION     0.0000
```

Figure 6.46   LMSP Multiple Target Direction Summary for Event 374

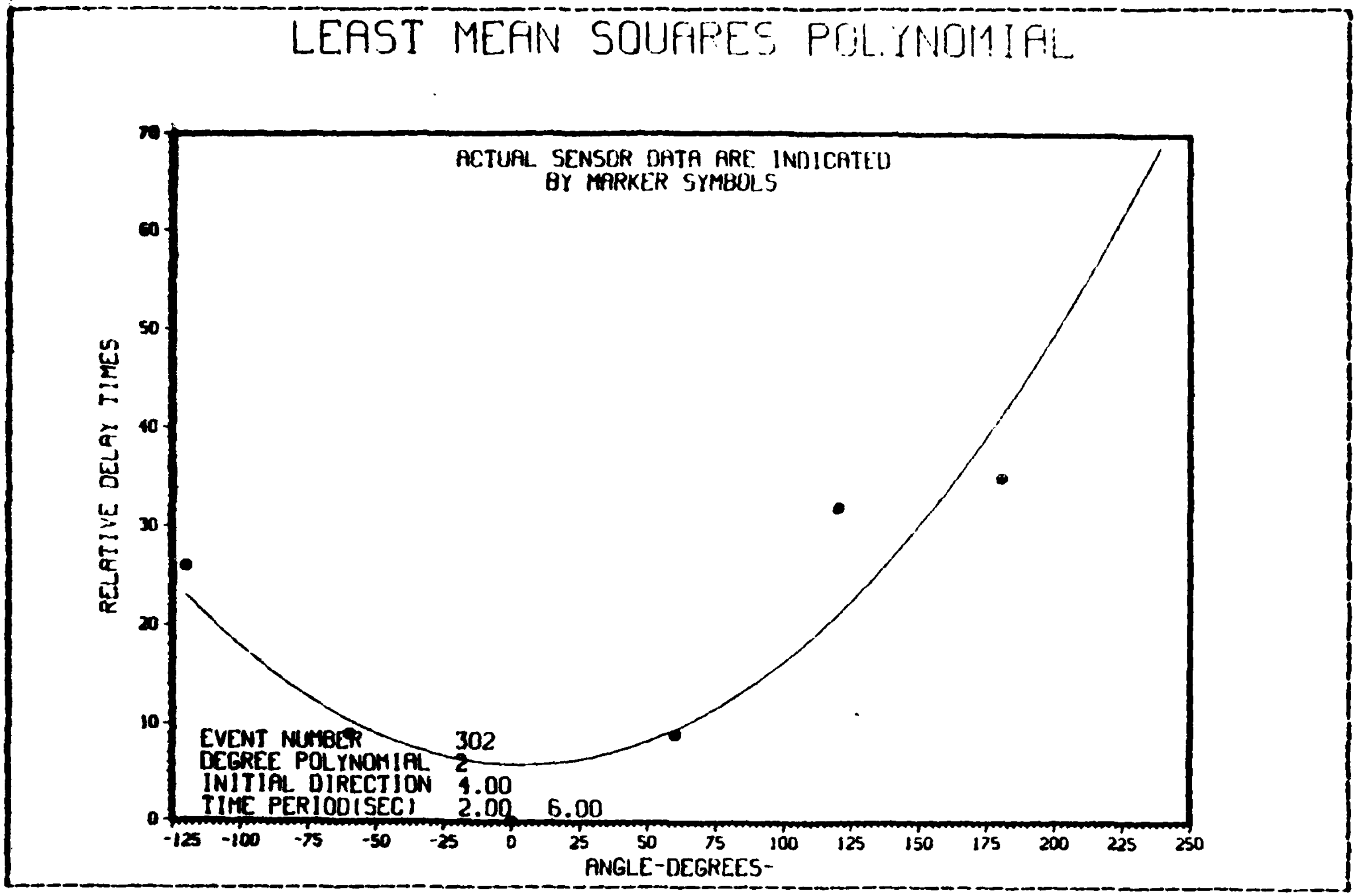

Figure 6.47 LMSP Initial Direction for Event 302

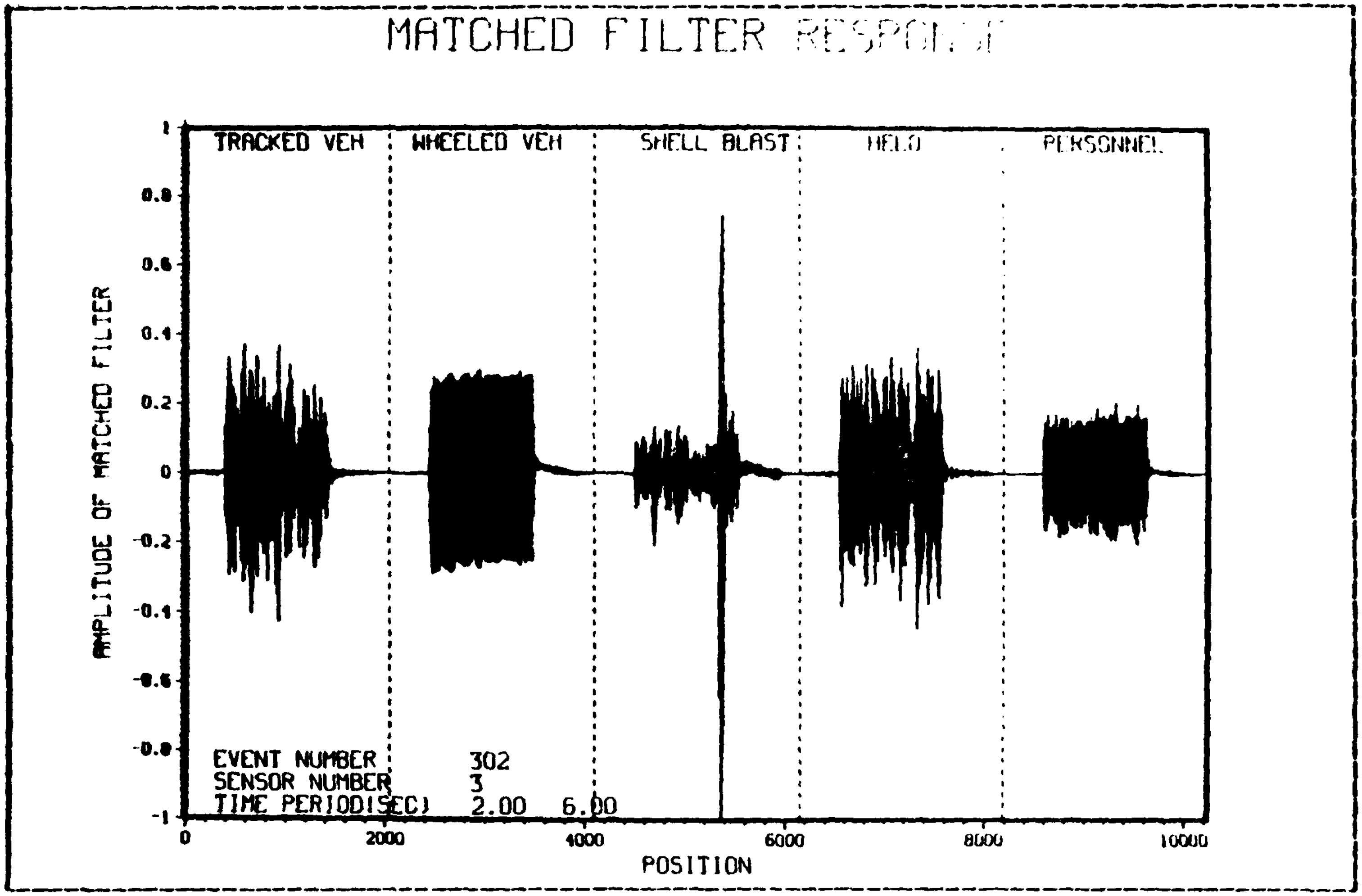

Figure 6.48 Matched Filter Response for Event 302

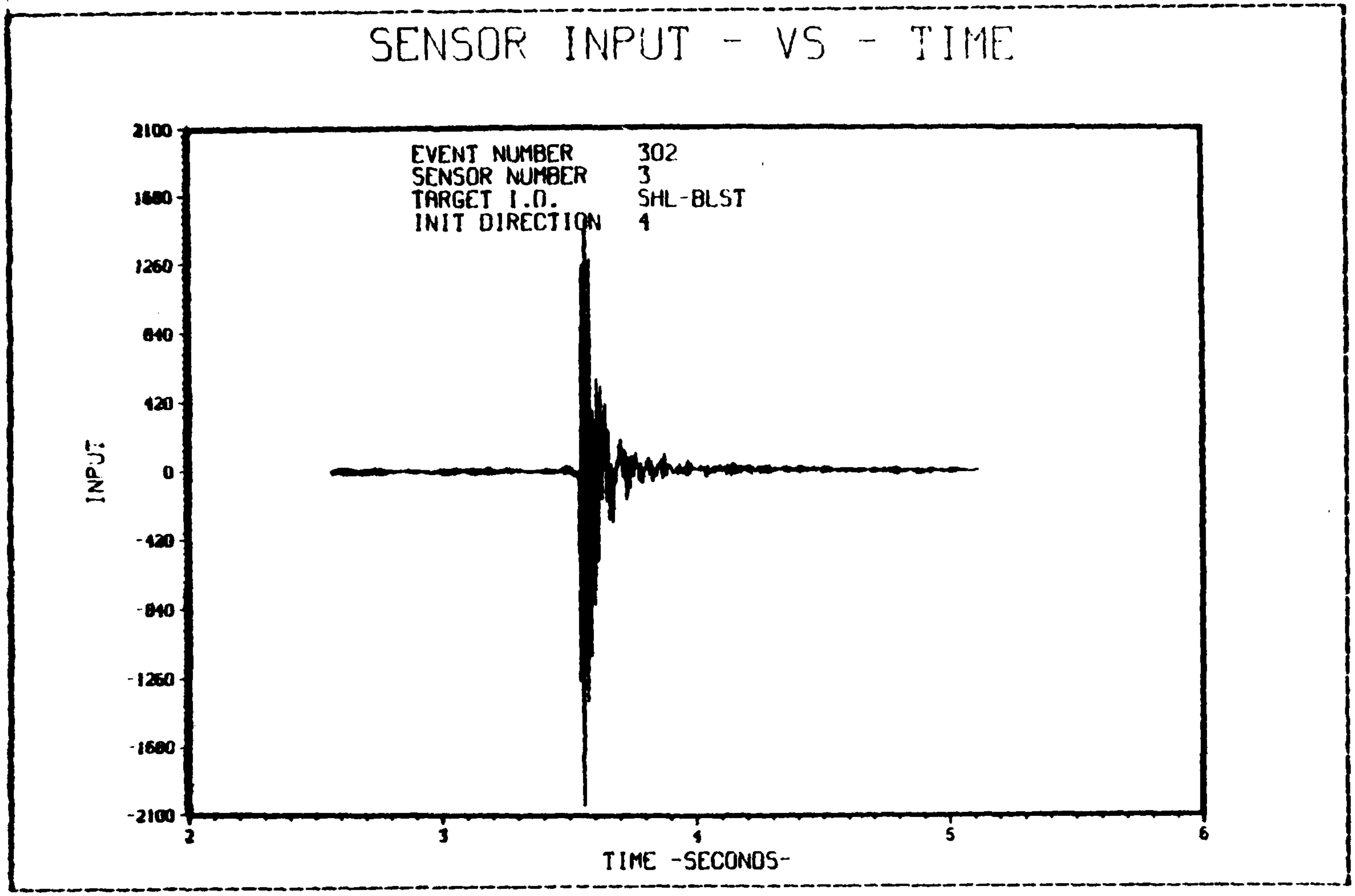

Figure 6.49 Amplitude Response for Event 302

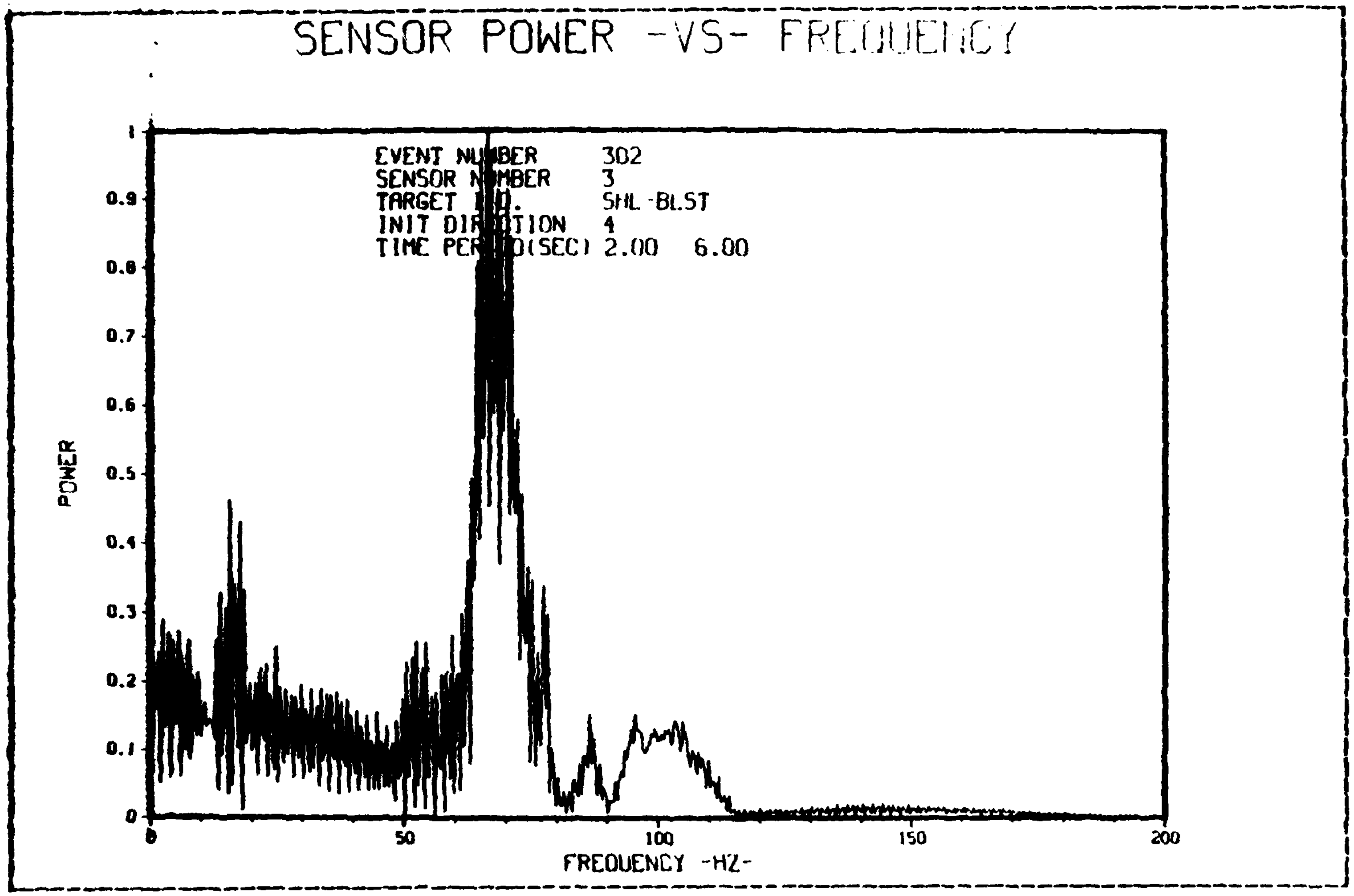

Figure 6.50 Frequency Response for Event 302

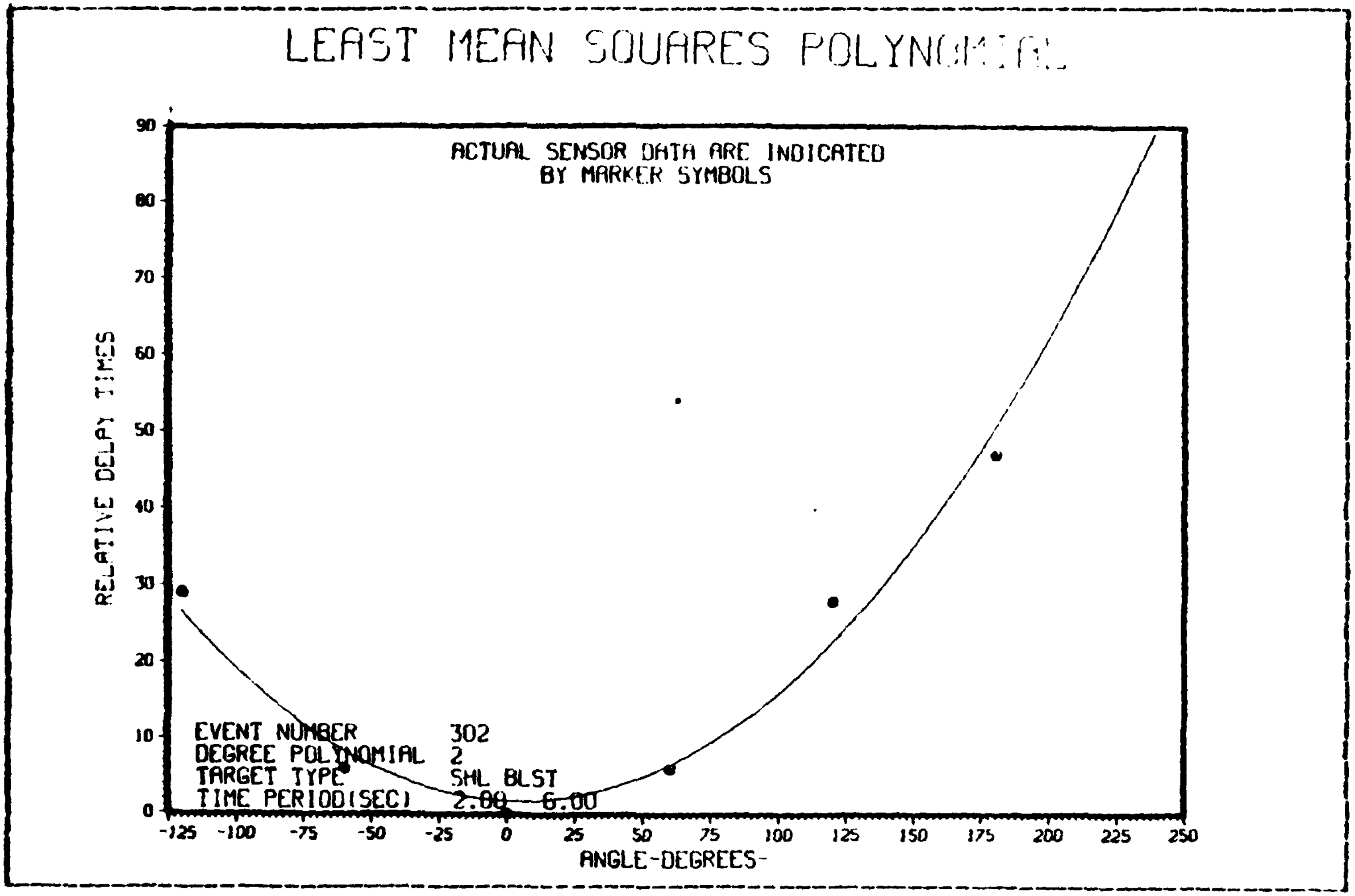

Figure 6.51 LMSP Matched Filter Direction for Event 302

```
MULTIPLE TARGET - MATCHED FILTER OUTPUT

EVENT NUMBER     302

TIME PERIOD(SEC) 2.00   6.00

SHELL BLAST        DIRECTION - 6.00

SIMULATED TRKD VEHICLE TARGET FREQUENCY    0.00
        AMPLITUDE     0.0000
        DIRECTION     0.0000
SIMULATED WHLD VEHICLE TARGET FREQUENCY    0.00
        AMPLITUDE     0.0000
        DIRECTION     0.0000
SIMULATED HELICOPTER TARGET FREQUENCY      0.00
        AMPLITUDE     0.0000
        DIRECTION     0.0000
SIMULATED PERSONNEL TARGET FREQUENCY       0.00
        AMPLITUDE     0.0000
        DIRECTION     0.0000
```

Figure 6.52   LMSP Multiple Target Diraction Summary for Event 302

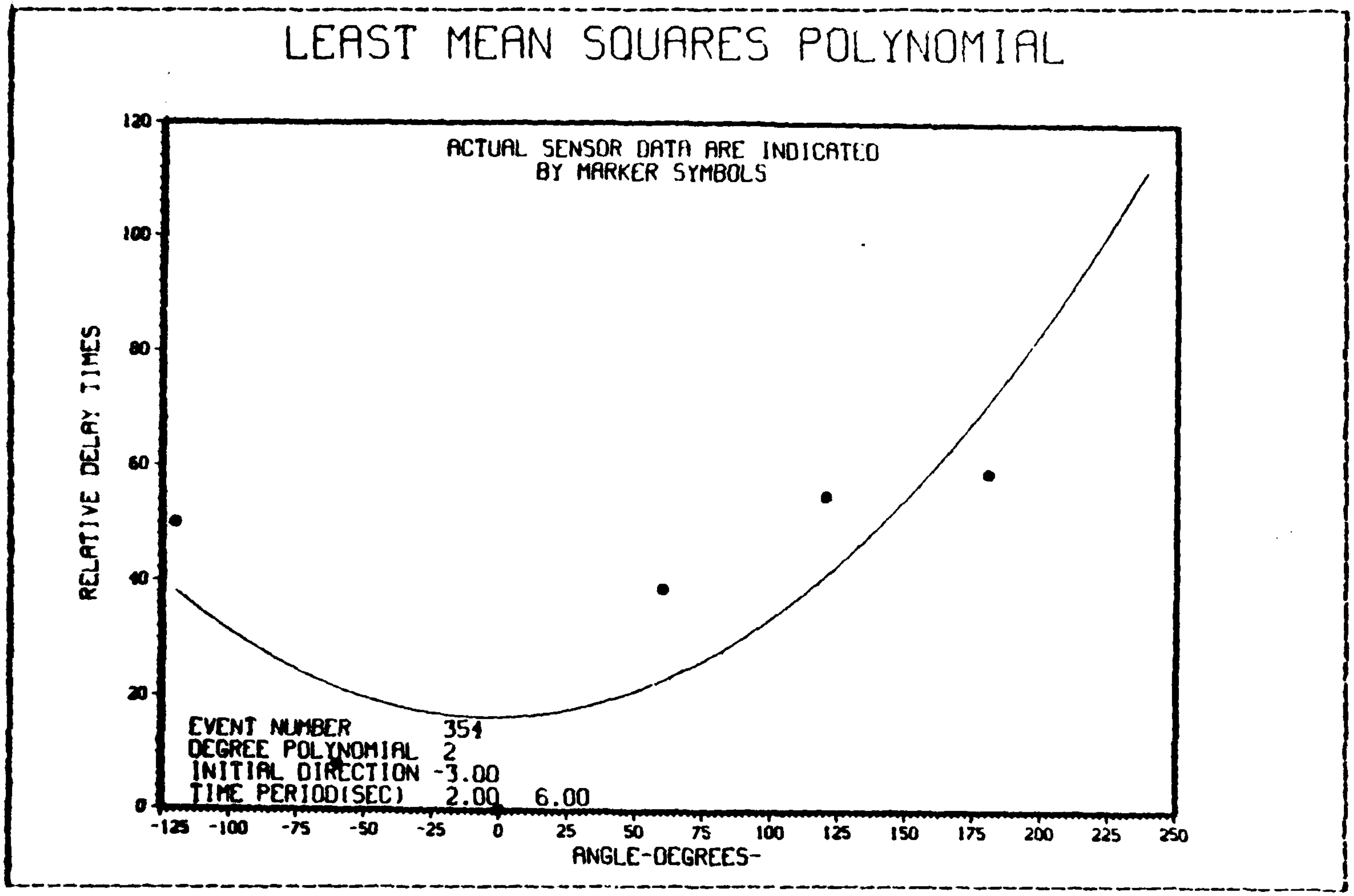

Figure 6.53 LMSP Initial Direction for Event 354 (2 - 6sec)

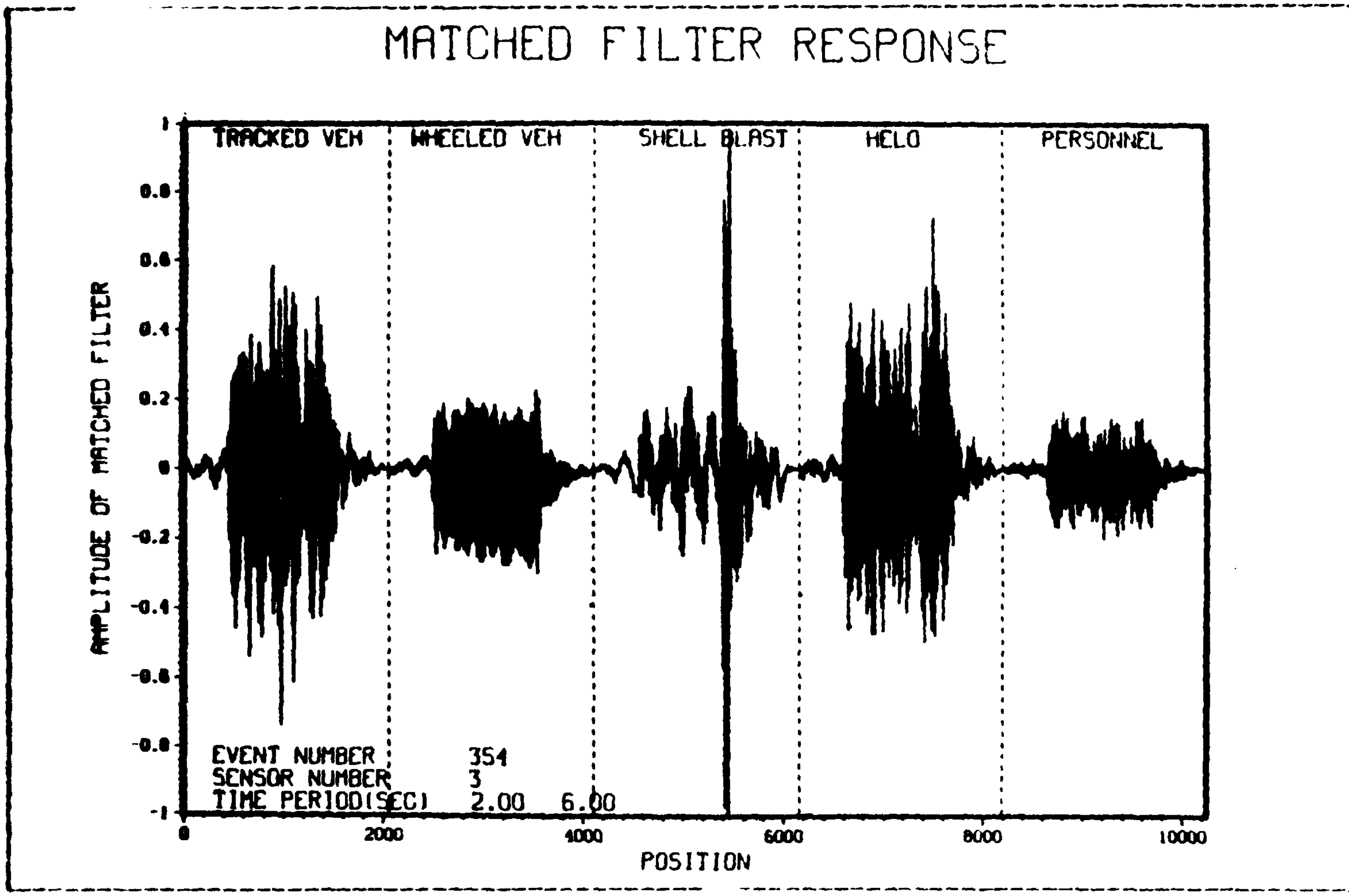

Figure 6.54 Matched Filter Res use for Event 354 (2 - 6sec)

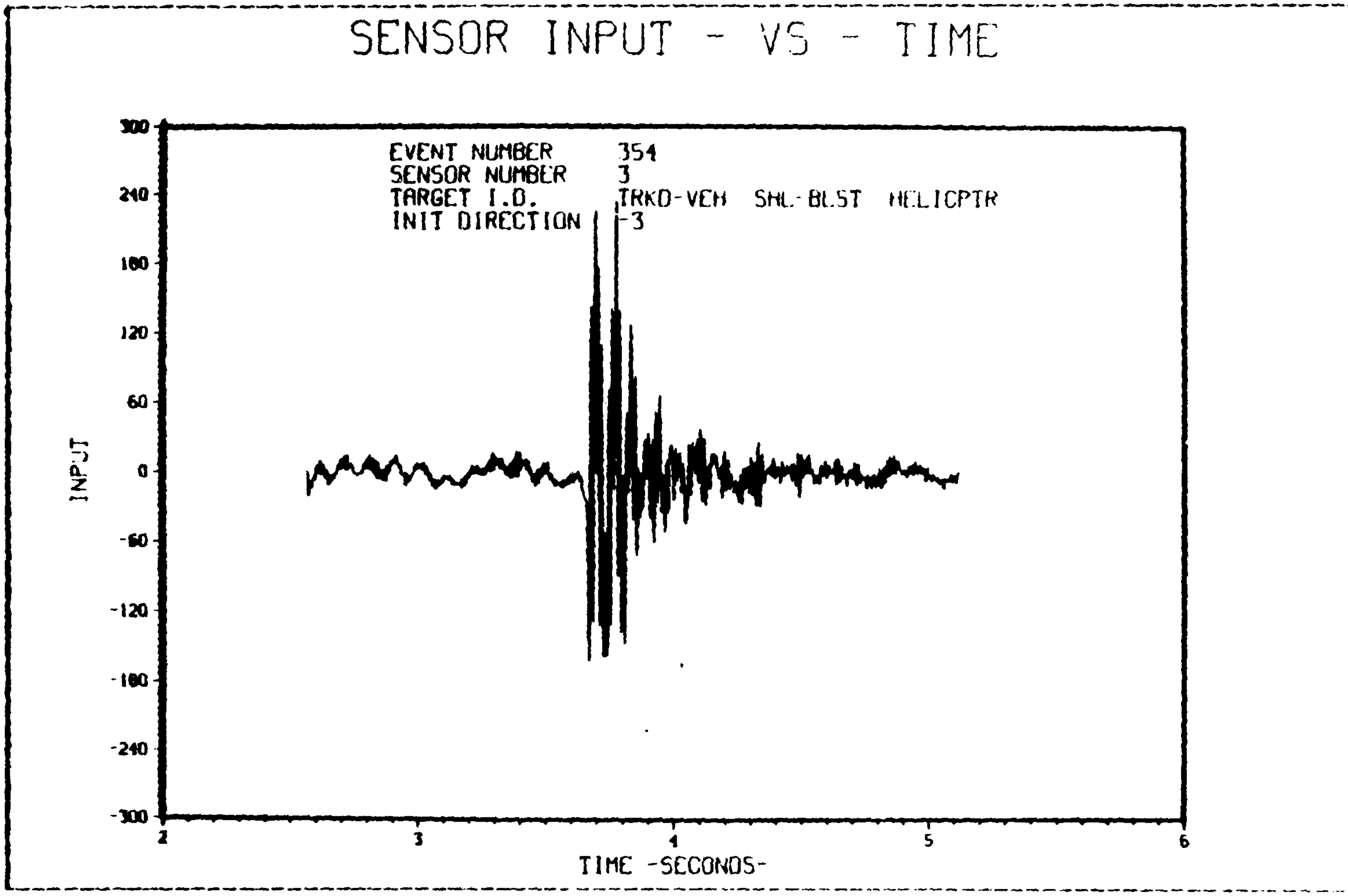

Figure 6.55 Amplitude Response for Event 354 (2 - 6sec)

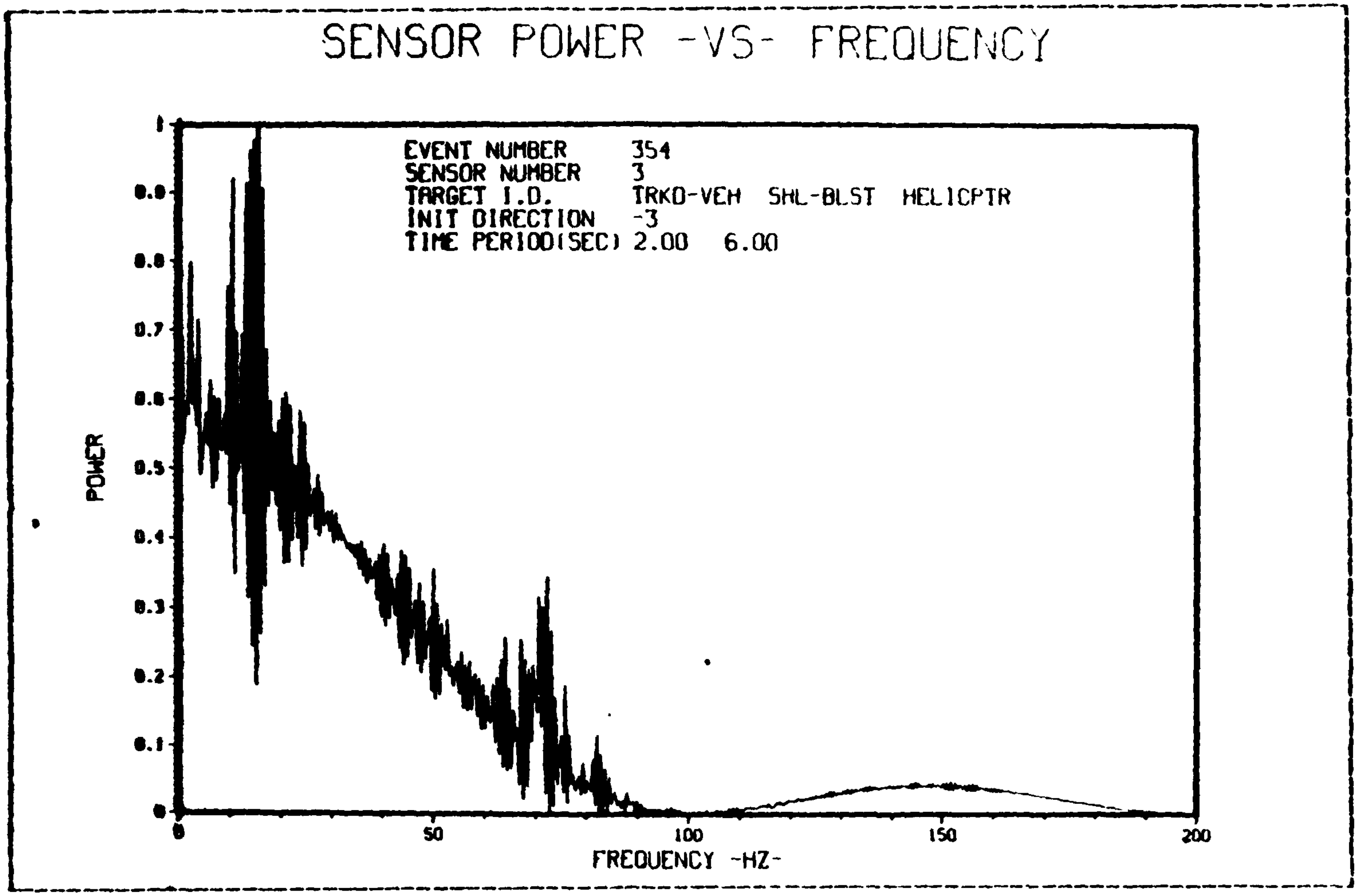

Figure 6.56 Frequency Response for Event 354 (2 - 6sec)

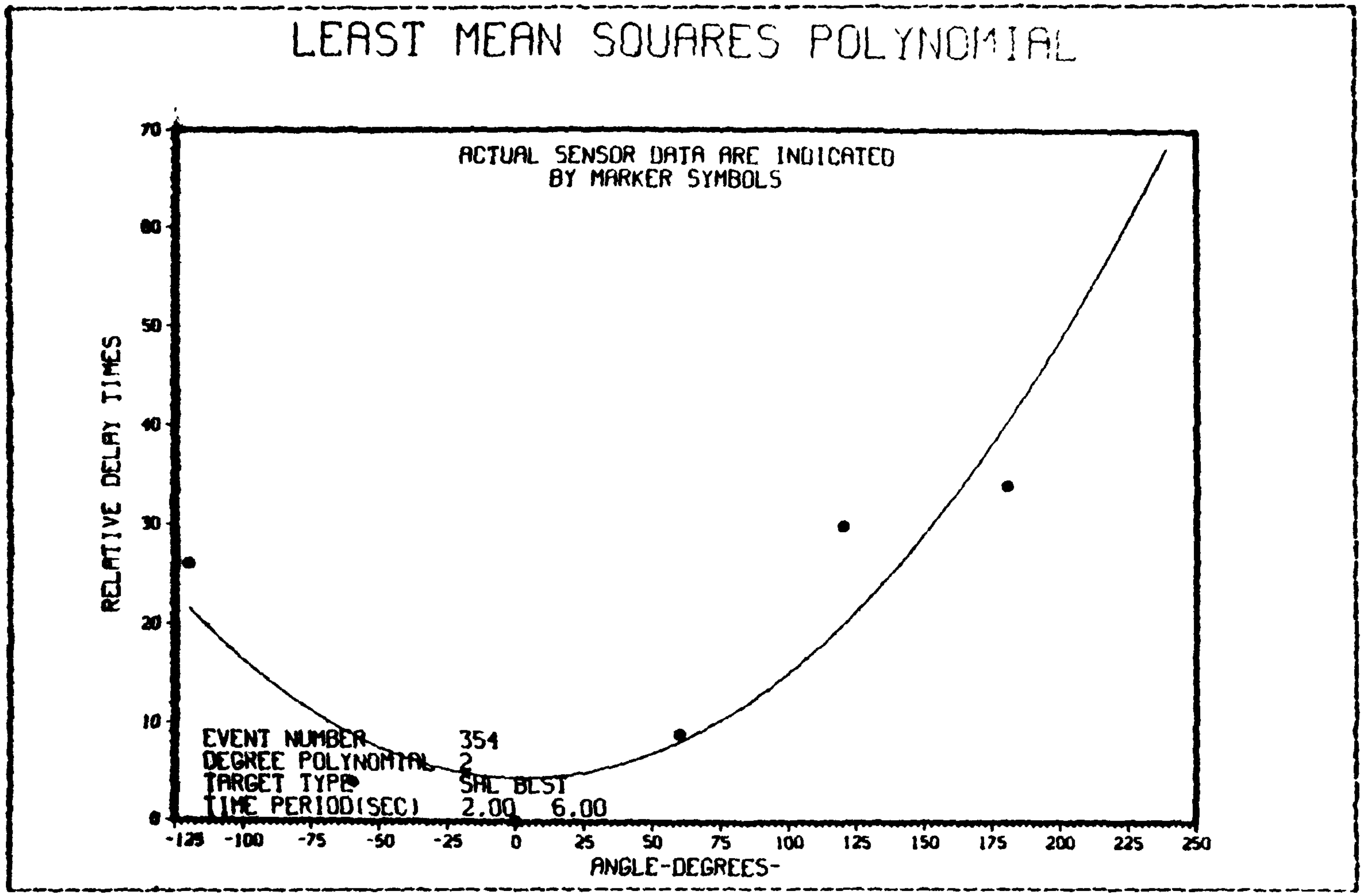

Figure 6.57 LMSP Matched Filter Direction for Event 354 (2 - 6sec)

MULTIPLE TARGET - MATCHED FILTER OUTPUT

```
EVENT NUMBER      354

TIME PERIOD(SEC) 2.00   6.00

TRACKED VEHICLE   DIRECTION - 332.00


SHELL BLAST       DIRECTION - 3.00

HELICOPTER        DIRECTION - 355.00



SIMULATED TRKD VEHICLE TARGET FREQUENCY     0.00
          AMPLITUDE     0.0000
          DIRECTION     0.0000
SIMULATED WHLD VEHICLE TARGET FREQUENCY     0.00
          AMPLITUDE     0.0000
          DIRECTION     0.0000
SIMULATED HELICOPTER TARGET FREQUENCY       0.00
          AMPLITUDE     0.0000
          DIRECTION     0.0000
SIMULATED PERSONNEL TARGET FREQUENCY        0.00
          AMPLITUDE     0.0000
          DIRECTION     0.0000
```

Figure 6.58 LMSP Multiple Target Direction Summary Event 354 (2 - 6sec)

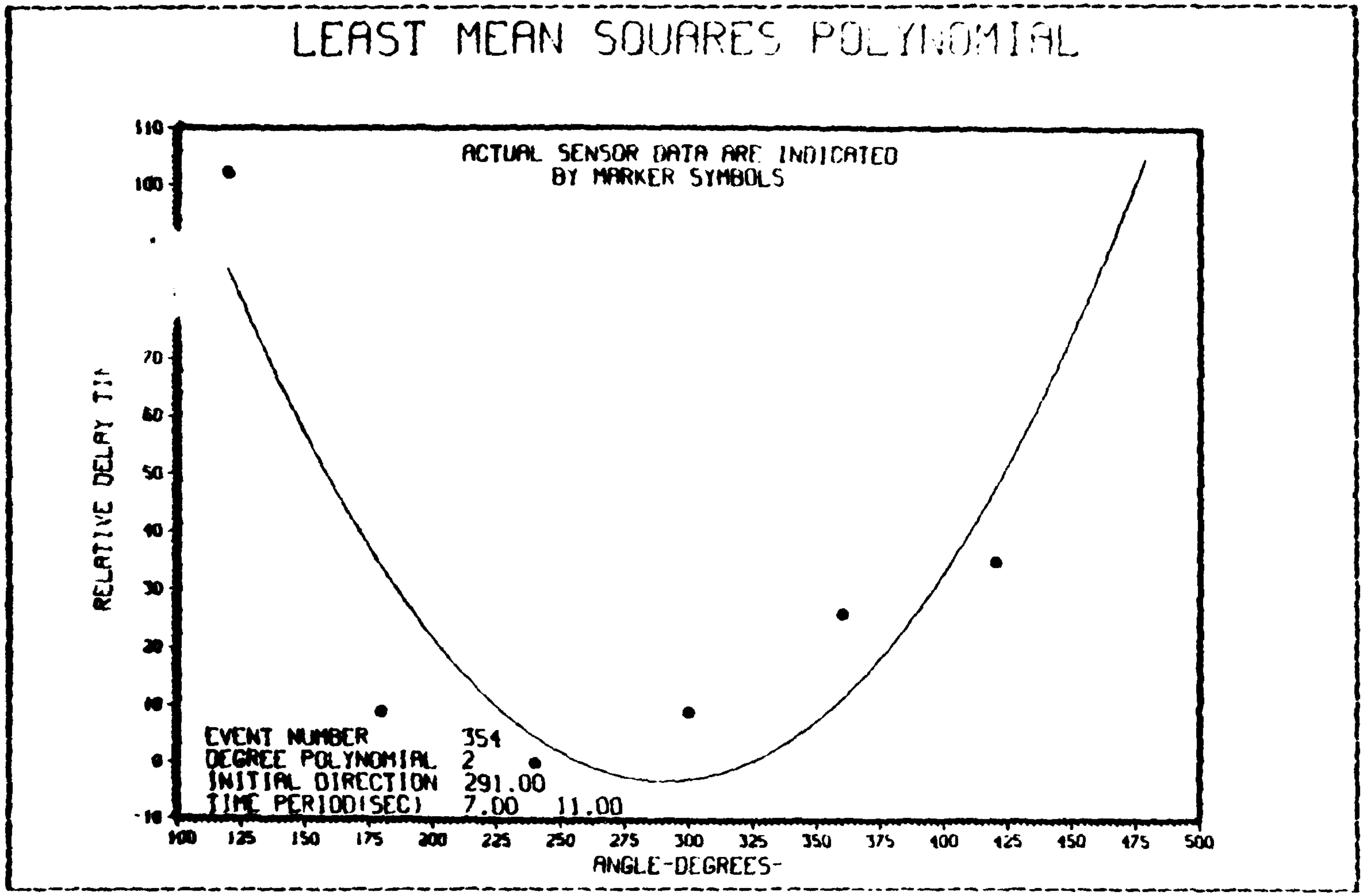

Figure 6.59 LMSP Initial Direction for Event 354 (7 - 11sec)

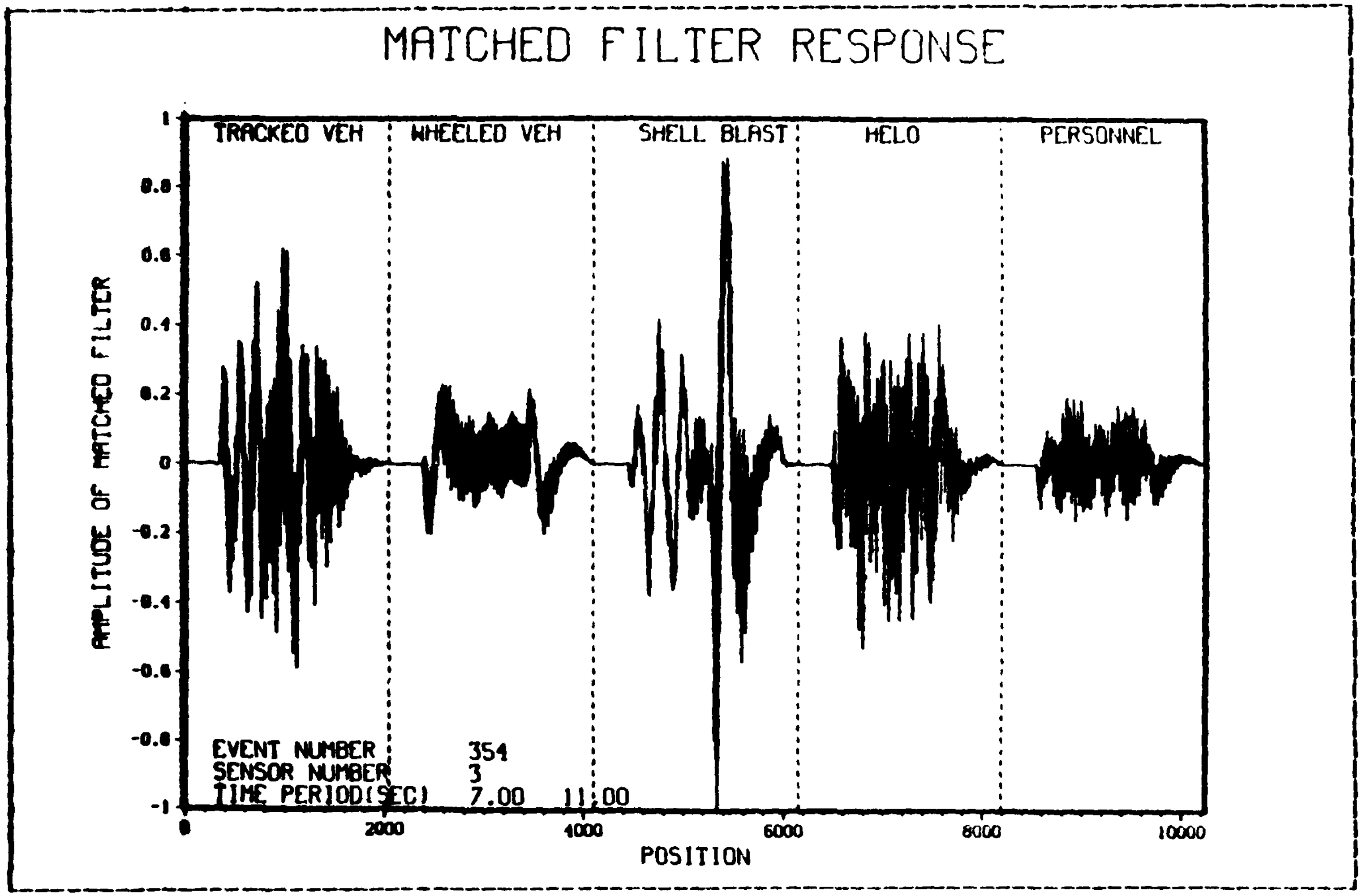

Figure 6.60 Matched Filter Response for Event 354 (7 - 11sec)

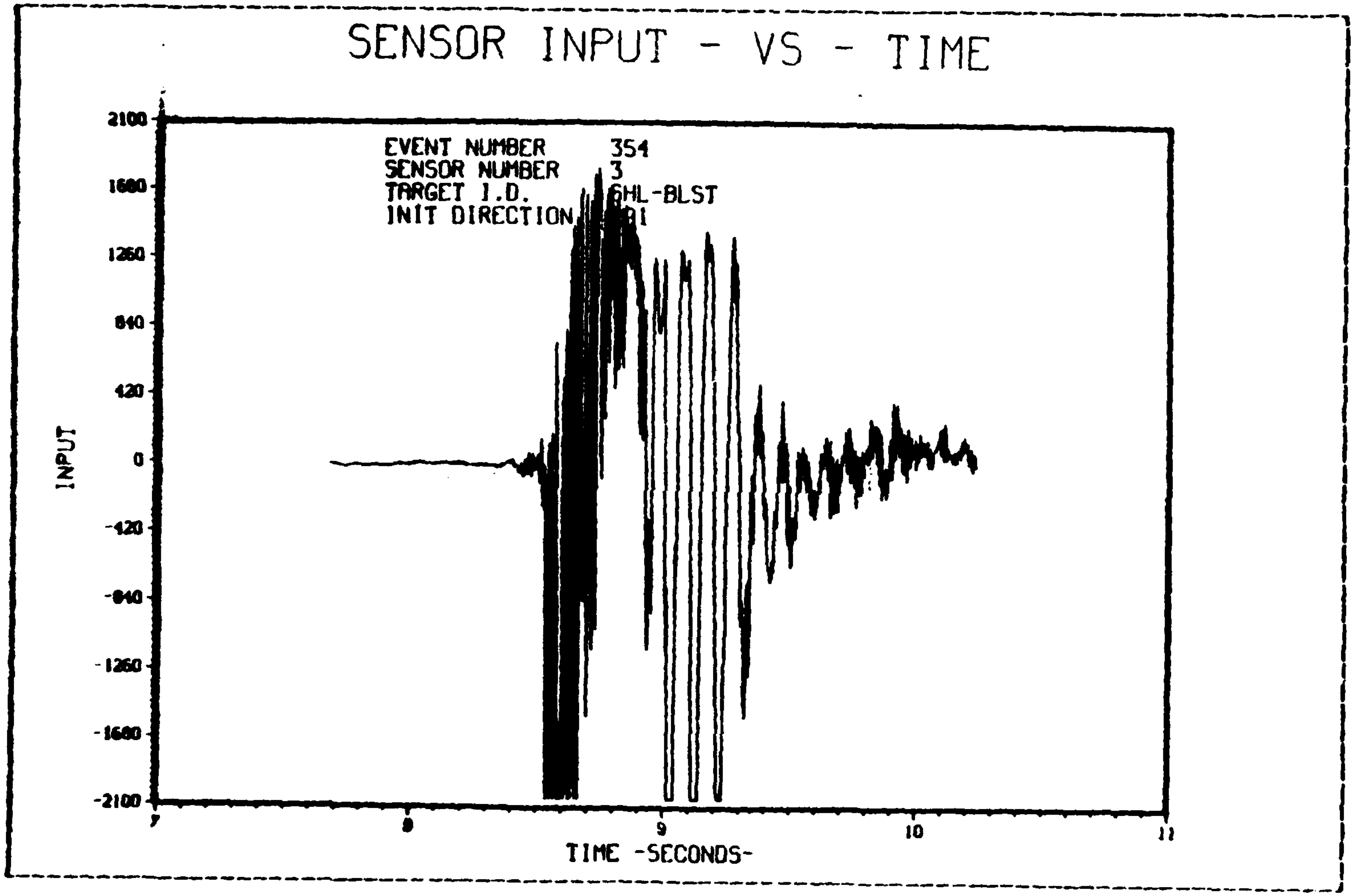

Figure 6.61 Amplitude Response for Event 354 (7 - 11sec)

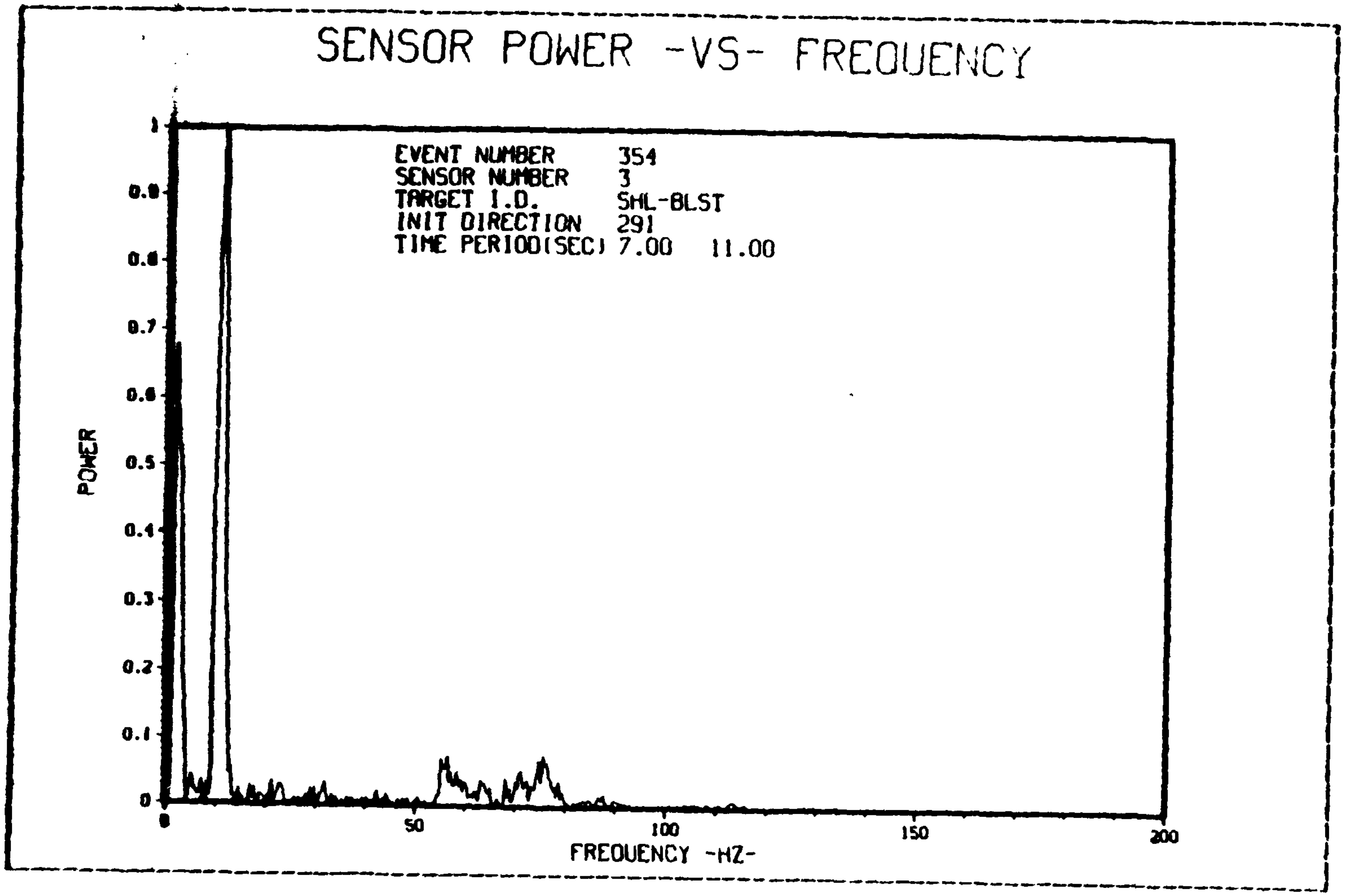

Figure 6.62 Frequency Response for Event 354 (7 - 11sec)

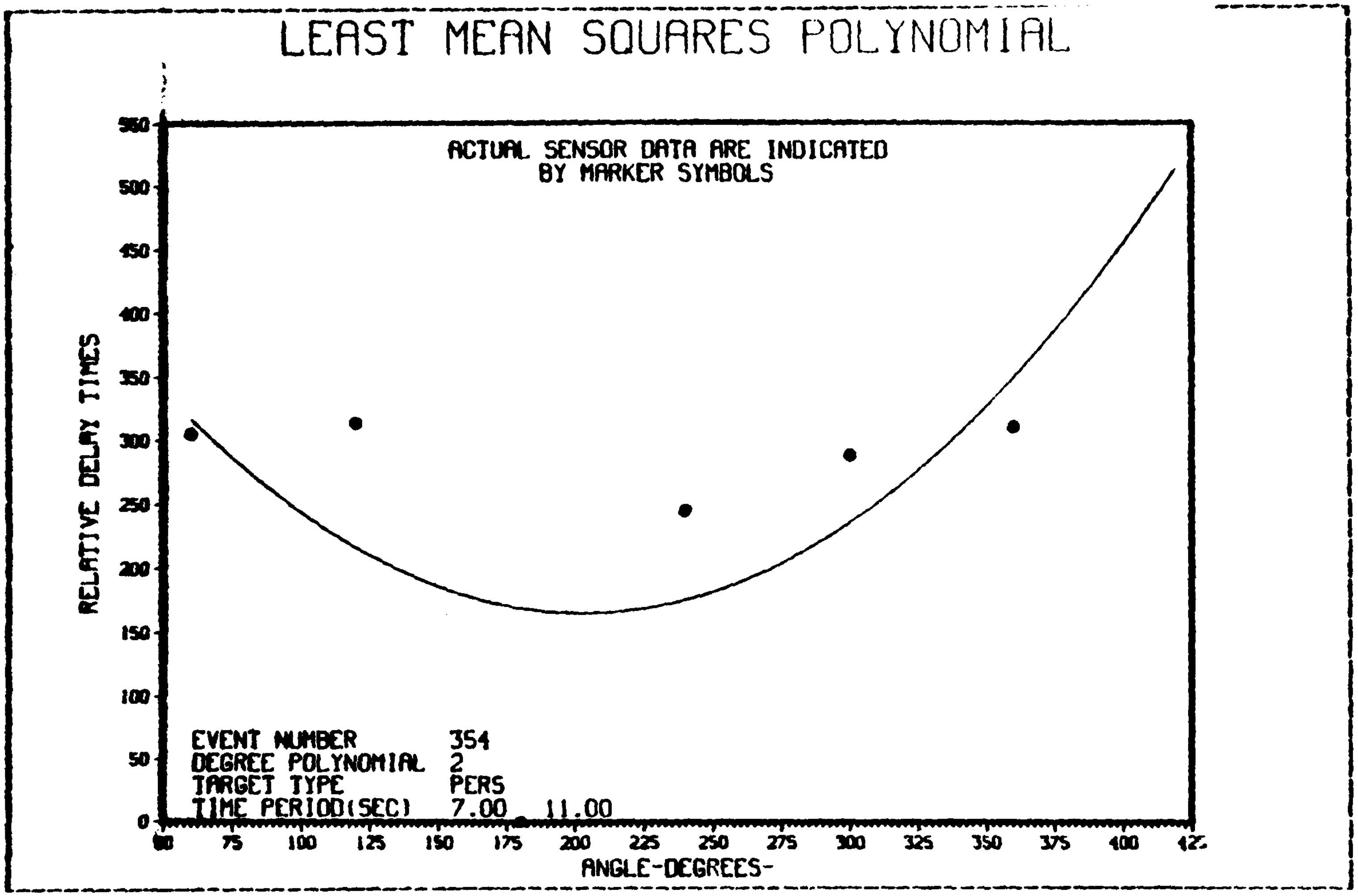

Figure 6.63 LMSP Matched Filter Direction for Event 354 (7 - 11sec)

MULTIPLE TARGET - MATCHED FILTER OUTPUT

```
EVENT NUMBER      354

TIME PERIOD(SEC) 7.00   11.00

TRACKED VEHICLE   DIRECTION - 291.00

WHEELED VEHICLE   DIRECTION - 291.00

SHELL BLAST       DIRECTION - 291.00


PERSONNEL         DIRECTION - 204.00

SIMULATED TRKD VEHICLE TARGET FREQUENCY    0.00
          AMPLITUDE     0.0000
          DIRECTION     0.0000
SIMULATED WHLD VEHICLE TARGET FREQUENCY    0.00
          AMPLITUDE     0.0000
          DIRECTION     0.0000
SIMULATED HELICOPTER TARGET FREQUENCY      0.00
          AMPLITUDE     0.0000
          DIRECTION     0.0000
SIMULATED PERSONNEL TARGET FREQUENCY       0.00
          AMPLITUDE     0.0000
          DIRECTION     0.0000
```

Figure 6.64   LMSP Multiple Target Summary Event 354 (7 - 11sec)

VII. CONCLUSIONS AND RECOMMENDATIONS

The ability of the digital matched filter to detect and correctly identify actual discrete single target types was excellent. The adaptive enhancement of the matched filter scheme was found to sharpen the matched filter responses. The complications of multiple targets and continuous targets proved to be less successful. Lack of high signal to noise ratio sample signals for use as filters reduced the abiltiy of the filters to match the signals. As would be expected, the simulated target identification and direction finding operations met with success for both single and multiple targets.

The simulated data validated the usefulness of the least mean squares curve fitting method for target direction finding. This algorithm was noted to be useful in both the relative peak amplitude response method for recoil/blast targets and the matched filter peak position method for all targets. The highest accurracies were found using second degree polynomials. This was due to the reduced noise sensitivity of lower degree polynomials. Conversly, significant errors were found in the directions determined by the phase difference algorithm. These errors were possibly due to round-off error sensitivity in the software/hardware implementation. Experimental data could not be used to effectively crosscheck this finding since most of the experimental data targets were at zero degrees and the phase difference routine seemed to seek zero degrees.

A significant result was the accuracy of the blast/recoil target direction found using only the peak amplitude responses. Directions could be found using only the relative amplitude peak positions for the array sensors and the

least mean squares curve fitting routine. This result indicated a possible counter-fire application using a greatly simplified system. This finding is felt to be significant since artillery type targets are the highest priority target type. The discrete nature of the blast/recoil seismic signals would also allow for ready separation of even a large number of combined hostile and friendly signal sources. This would allow for observerless adjustment of fire onto hostile targets. Artillery and mortar targets may, infact, be the only target types detectable at the ranges specified for a long range seismic system.

It is recommeded that further study be made in to the possible implementation of the least mean square curve fitting of the peak sensor amplitudes responses in a counter-fire system. Digital matched filters for seismic target identification and direction finding may also prove effective after further experimentation with optimum sample signal filters for the various target types. Additionally, the matched filter response may possibly be enhanced by preprocessing the seismic signals through adaptive noise cancellors.

Acoustic vice seismic matched filtering with directional microphones may be useful in target identification. Once the target has been identified, a matched filter/least mean squares based direction finding scheme could then be attempted.

APPENDIX A

USERS MANUAL

The software developed provided for interactive program operation. However, further information must be provided for an initial system setup and correct program operation. To begin with, the seismic data must be transferred from magnetic tape to the IBM 3033's Mass Storage System (MSS). The data must then be transfered to the DISSPLA user's disk for analysis of the program. These data transfers may be accomplished using Job Control Language (JCL) procedures.

The magnetic tape volume must first be scanned to determine the storage format of its files. The JCL procedure TSCAN provides this information. A sample TSCAN job follows:

```
//JLJV1677 JOB (3026,0304),'SMC-1677 JOHNSTON',CLASS=F
//   EXEC TSCAN,VOLIN=PARK1,DCBIN='DEN=2',UNITIN='3400-4'
//   EXEC TSCAN,VOLIN=PARK2,DCBIN='DEN=2',UNITIN='3400-4'
//   EXEC TSCAN,VOLIN=PARK3,DCBIN='DEN=2',UNITIN='3400-4'
//   EXEC TSCAN,VOLIN=PARK4,DCBIN='DEN=2',UNITIN='3400-4'
//
```

Once the tape scan is completed, the tape files and comments can be transferred to the MSS. Prior to this transfer however, space in the MSS must be made for these files. The procedure IEFBR14 is used for this purpose. A sample job follows:

```
//JLJTN74A JOB (3026,0304),'SMC1677 JOHNSTON',CLASS=A
//*MAIN ORG=NPGVM1.0131P
//   EXEC PGM=IEFBR14
//DD1 DD UNIT=3330V,MSVGP=PUB4B,DISP=(NEW,CATLG),
//          SPACE=(CYL,(4,4,3)),DSN=MSS.S3026.P302
```

```
/*
//  EXEC PGM=IEFBR14
//DD1 DD UNIT=3330V,MSVGP=PUB4B,DISP=(NEW,CATLG),
//        SPACE=(CYL,(4,4,3)),DSN=MSS.S3026.P314
/*
//  EXEC PGM=IEFBR14
//DD1 DD UNIT=3330V,MSVGP=PUB4B,DISP=(NEW,CATLG),
//        SPACE=(CYL,(4,4,3)),DSN=MSS.S3026.P319
/*
//
```

Each event is proceeded by a comment file for that event. These comment files can be identified from the TSCAN output as a file containing only one record. The files containing nine or eighteen records are the sensor data files for the events. Files of nine records in length are events using a circular array of nine sensors designated as a type A33 array. These sensors are all vertical motion-sensing geophones. The eighteen record files contain six sensor groups of three geophones. A circular array is designated type A31 and a linear array is a type A32 array. The three geophones for each group sense either radial, transverse or vertical motion. A JCL routine, using the procedure IEBGENER, transfers the event comment and sensor data. A sample IEBGENNER job follows:

```
//JLJ11677 JOB (3026,0304),'JOHNSTON SMC1677',CLASS=P
//*MAIN ORG=NPGVM1.0131P
//*
//* CP/CMS SUBMIT     IEBGENER JCL
//*
//*       COPY TAPE FILES TO MSS.S3026.P319
//*
//  EXEC PGM=IEBGENER
//SYSPRINT DD SYSOUT=A
//SYSUT1 DD UNIT=3400-4,VOL=SER=PARK2,DISP=(,PASS),
```

```
//            LABEL=(1,NL,,IN),
//    DCB=(RECFM=FB,LRECL=64,BLKSIZE=2048,DEN=2,OPTCD=Q)
//SYSUT2 DD  DISP=SHR,DSN=MSS.S3026.COMMENTS(COM319)
//SYSIN DD DUMMY
//* * * * * * * * * * * * * * * * * * * * *
//COPY  PROC FILE=,MEM=
//  EXEC PGM=IEBGENER
//SYSPRINT DD SYSOUT=A
//SYSUT1 DD UNIT=3400-4,VOL=SER=PARK2,DISP=(,PASS),
//       LABEL=(&FILE,NL,,IN),DCB=(RECFM=F,BLKSIZE=2048,DEN=2)
//SYSUT2 DD  DISP=SHR,DSN=MSS.S3026.P319(&MEM)
//SYSIN DD DUMMY
//    PEND
/*
//* * * * * * * * * * * * * * * * * * * * *
//    EXEC COPY,FILE=342,MEM=SEN1
//    EXEC COPY,FILE=343,MEM=SEN2
//    EXEC COPY,FILE=344,MEM=SEN3
//    EXEC COPY,FILE=345,MEM=SEN4
//    EXEC COPY,FILE=346,MEM=SEN5
//    EXEC COPY,FILE=347,MEM=SEN6
//    EXEC COPY,FILE=348,MEM=SEN7
//    EXEC COPY,FILE=349,MEM=SEN8
//    EXEC COPY,FILE=350,MEM=SEN9
//    EXEC COPY,FILE=351,MEM=SEN10
//    EXEC COPY,FILE=352,MEM=SEN11
//    EXEC COPY,FILE=353,MEM=SEN12
//    EXEC COPY,FILE=354,MEM=SEN13
//    EXEC COPY,FILE=355,MEM=SEN14
//    EXEC COPY,FILE=356,MEM=SEN15
//    EXEC COPY,FILE=357,MEM=SEN16
//    EXEC COPY,FILE=358,MEM=SEN17
//    EXEC COPY,FILE=359,MEM=SEN18
//    EXEC COPY,FILE=360,MEM=SEN19
/*
```

```
//
```

Transfer of the d sired event data from MSS to the DISSPLA user's disk may now be performed. A batch fortran job with the appropri ILEDEFs to denote the various geophone's data is submitted. The RSCS/NET feature is used to send the output of this routine to the user's reader. A sample fortran job for nine sensors follows:

```
//JLJ83026 JOB (3026,0304),'JOHNSTON',CLASS=A
//*MAIN ORG=NPGVM1.0090P
//   EXEC FORTXCG,REGION.GO=1024K
//FORT.SYSIN DD *
C
      LOGICAL*1 INFO1(8),INFO2(8),INFO3(8),INFO4(8),INFO5(8)
      LOGICAL*1 INFO6(8),INFO7(8),INFO8(8),INFO9(8)
      INTEGER*2 DATA1(1020),DATA2(1020),DATA3(1020),DATA4(1020)
      INTEGER*2 DATA5(1020),DATA6(1020),DATA7(1020),DATA8(1020)
      INTEGER*2 DATA9(1020),DATB1(4096)
C
      DO 30 J=1,4
         READ(1,100) INFO1,DATA1
         READ(2,100) INFO2,DATA2
         READ(3,100) INFO3,DATA3
         READ(4,100) INFO4,DATA4
         READ(8,100) INFO5,DATA5
         READ(9,100) INFO6,DATA6
         READ(10,100)INFO7,DATA7
         READ(11,100)INFO8,DATA8
         READ(12,100)INFO9,DATA9
100     FORMAT(8A1,102(10A2))
        DO 10 I = 10,1020,10
       WRITE(6,101)DATA1(I - 9),DATA1(I - 8),DATA1(I - 7),
      1DATA1(I - 6),DATA1(I - 5),DATA1(I - 4),DATA1(I - 3),
      2DATA1(I - 2),DATA1(I - 1),DATA1(I)
```

```
10      CONTINUE
        DO 20 I = 10,1020,10
        WRITE(6,101)DATA2(I - 9),DATA2(I - 8),DATA2(I - 7),
       1DATA2(I - 6),DATA2(I - 5),DATA2(I - 4),DATA2(I - 3),
       2DATA2(I - 2),DATA2(I - 1),DATA2(I)
20      CONTINUE
        DO 40 I = 10,1020,10
        WRITE(6,101)DATA3(I - 9),DATA3(I - 8),DATA3(I - 7),
       1DATA3(I - 6),DATA3(I - 5),DATA3(I - 4),DATA3(I - 3),
       2DATA3(I - 2),DATA3(I - 1),DATA3(I)
40      CONTINUE
        DO 50 I = 10,1020,10
        WRITE(6,101)DATA4(I - 9),DATA4(I - 8),DATA4(I - 7),
       1DATA4(I - 6),DATA4(I - 5),DATA4(I - 4),DATA4(I - 3),
       2DATA4(I - 2),DATA4(I - 1),DATA4(I)
50      CONTINUE
        DO 60 I = 10,1020,10
        WRITE(6,101)DATA5(I - 9),DATA5(I - 8),DATA5(I - 7),
       1DATA5(I - 6),DATA5(I - 5),DATA5(I - 4),DATA5(I - 3),
       2DATA5(I - 2),DATA5(I - 1),DATA5(I)
60      CONTINUE
        DO 70 I = 10,1020,10
        WRITE(6,101)DATA6(I - 9),DATA5(I - 8),DATA6(I - 7),
       1DATA6(I - 6),DATA6(I - 5),DATA6(I - 4),DATA6(I - 3),
       2DATA6(I - 2),DATA6(I - 1),DATA6(I)
70      CONTINUE
        DO 80 I = 10,1020,10
        WRITE(6,101)DATA7(I - 9),DATA7(I - 8),DATA7(I - 7),
       1DATA7(I - 6),DATA7(I - 5),DATA7(I - 4),DATA7(I - 3),
       2DATA7(I - 2),DATA7(I - 1),DATA7(I)
80      CONTINUE
        DO 90 I = 10,1020,10
        WRITE(6,101)DATA8(I - 9),DATA8(I - 8),DATA8(I - 7),
       1DATA8(I - 6),DATA8(I - 5),DATA8(I - 4),DATA8(I - 3),
       2DATA8(I - 2),DATA8(I - 1),DATA8(I)
```

```
90     CONTINUE
       DO 91 I = 10,1020,10
       WRITE(6,101) DATA9(I - 9),DATA9(I - 8),DATA9(I - 7),
      1DATA9(I - 6),DATA9(I - 5),DATA9(I - 4),DATA9(I - 3),
      2DATA9(I - 2),DATA9(I - 1),DATA9(I)
91     CONTINUE
101     FORMAT(I6,I6,I6,I6,I6,I6,I6,I6,I6,I6)
30      CONTINUE
        STOP
        END
/*
//GO.FT01F001 DD DISP=SHR,DSN=MSS.S3026.P383(SEN1)
//GO.FT02F001 DD DISP=SHR,DSN=MSS.S3026.P383(SEN2)
//GO.FT03F001 DD DISP=SHR,DSN=MSS.S3026.P383(SEN3)
//GO.FT04F001 DD DISP=SHR,DSN=MSS.S3026.P383(SEN4)
//GO.FT08F001 DD DISP=SHR,DSN=MSS.S3026.P383(SEN5)
//GO.FT09F001 DD DISP=SHR,DSN=MSS.S3026.P383(SEN6)
//GO.FT10F001 DD DISP=SHR,DSN=MSS.S3026.P383(SEN7)
//GO.FT11F001 DD DISP=SHR,DSN=MSS.S3026.P383(SEN8)
//GO.FT12F001 DD DISP=SHR,DSN=MSS.S3026.P383(SEN9)
//GO.SYSIN  DD  *
/*
//
```

A sample job for a six sensor group array follows:

```
//JLJ83026 JOB  (3026,0304),'JOHNSTON',CLASS=A
//*MAIN ORG=NPGVM1.0090P
//  EXEC FORTXCG,REGION.GO=1024K
//FORT.SYSIN DD *
C
       LOGICAL*1 INFO1(8),INFO2(8),INFO3(8),INFO4(8),INFO5(8)
       LOGICAL*1 INFO6(8),INFO7(8),INFO8(8),INFO9(8)
       INTEGER*2 DATA1(1020),DATA2(1020),DATA3(1020),DATA4(1020)
       INTEGER*2 DATA5(1020),DATA6(1020),DATA7(1020),DATA8(1020)
       INTEGER*2 DATA9(1020),DATB1(4096)
```

```
C
      DO 30 J=1,4
         READ(1,100) INFO1,DATA1
         READ(2,100) INFO2,DATA2
         READ(3,100) INFO3,DATA3
         READ(4,100) INFO4,DATA4
         READ(8,100) INFO5,DATA5
         READ(9,100) INFO6,DATA6
100   FORMAT(8A1,102(10A2))
      DO 10 I = 10,1020,10
      WRITE(6,101) DATA1(I - 9),DATA1(I - 8),DATA1(I - 7),
     1DATA1(I - 6),DATA1(I - 5),DATA1(I - 4),DATA1(I - 3),
     2DATA1(I - 2),DATA1(I - 1),DATA1(I)
10    CONTINUE
      DO 20 I = 10,1020,10
      WRITE(6,101) DATA2(I - 9),DATA2(I - 8),DATA2(I - 7),
     1DATA2(I - 6),DATA2(I - 5),DATA2(I - 4),DATA2(I - 3),
     2DATA2(I - 2),DATA2(I - 1),DATA2(I)
20    CONTINUE
      DO 40 I = 10,1020,10
      WRITE(6,101) DATA3(I - 9),DATA3(I - 8),DATA3(I - 7),
     1DATA3(I - 6),DATA3(I - 5),DATA3(I - 4),DATA3(I - 3),
     2DATA3(I - 2),DATA3(I - 1),DATA3(I)
40    CONTINUE
      DO 50 I = 10,1020,10
      WRITE(6,101) DATA4(I - 9),DATA4(I - 8),DATA4(I - 7),
     1DATA4(I - 6),DATA4(I - 5),DATA4(I - 4),DATA4(I - 3),
     2DATA4(I - 2),DATA4(I - 1),DATA4(I)
50    CONTINUE
      DO 60 I = 10,1020,10
      WRITE(6,101) DATA5(I - 9),DATA5(I - 8),DATA5(I - 7),
     1DATA5(I - 6),DATA5(I - 5),DATA5(I - 4),DATA5(I - 3),
     2DATA5(I - 2),DATA5(I - 1),DATA5(I)
60    CONTINUE
```

```
      DO 70 I = 10,1020,10
      WRITE(6,101)DATA6(I - 9),DATA6(I - 8),DATA6(I - 7),
     1DATA6(I - 6),DATA6(I - 5),DATA6(I - 4),DATA6(I - 3),
     2DATA6(I - 2),DATA6(I - 1),DATA6(I)
70    CONTINUE
101     FORMAT(I6,I6,I6,I6,I6,I6,I6,I6,I6,I6)
30      CONTINUE
        STOP
        END
/*
//GO.FT01F001 DD DISP=SHR,DSN=MSS.S3026.P350(SEN3)
//GO.FT02F001 DD DISP=SHR,DSN=MSS.S3026.P350(SEN6)
//GO.FT03F001 DD DISP=SHR,DSN=MSS.S3026.P350(SEN9)
//GO.FT04F001 DD DISP=SHR,DSN=MSS.S3026.P350(SEN12)
//GO.FT08F001 DD DISP=SHR,DSN=MSS.S3026.P350(SEN15)
//GO.FT09F001 DD DISP=SHR,DSN=MSS.S3026.P350(SEN18)
//GO.SYSIN  DD  *
/*
//
```

Two files will be returned to user's reader. The first file is the listing and diagnostics file and should be purged. The second file should be named SEN DATA. SEN DATA must now be edited. Delete the first seven lines of the file and issue the command LREC 80 to set the proper file record length.

The interactive program can be run with the complete collection of files listed in the exec MATCH. The MATCH EXEC follows:

```
&TRACE OFF
FORTGI MFILTER
GLOBAL TXTLIB FORTMOD2 MOD2EEH IMSLSP NONIMSL
FILEDEF 10 TERMINAL
FILEDEF 05 DISK SEN DATA (PERM)
FILEDEF 07 DISK COM DATA (PERM)
```

```
FI 4 DISK FILTER DATA (RECFM VS PERM
FILEDEF 18 DISK DISSPLA METAFILE T4 (RECFM VBS LRECL
                                        19065 BLOCK 19069
EXEC DISSPLA MFILTER
```

Entry parameters, such as the number of sensors in the array and the sampling rate, can be found in the NOSC data log for the event under study. All other interactive entries are user selected options or are self explanatory. [Ref. 12]

APPENDIX B

SAMPLE INTERACTIVE PROGRAM SESSION

```
match
G1 COMPILER ENTERED
SOURCE ANALYZED
PROGRAM NAME = MAIN
*  NO DIAGNOSTICS GENERATED
SOURCE ANALYZED
PROGRAM NAME = ANGLE
*  NO DIAGNOSTICS GENERATED
SOURCE ANALYZED
PROGRAM NAME = TIMOUT
*  NO DIAGNOSTICS GENERATED
SOURCE ANALYZED
PROGRAM NAME = FREQOT
*  NO DIAGNOSTICS GENERATED
SOURCE ANALYZED
PROGRAM NAME = MATCH
*  NO DIAGNOSTICS GENERATED
SOURCE ANALYZED
PROGRAM NAME = MYDATA
*  NO DIAGNOSTICS GENERATED
SOURCE ANALYZED
PROGRAM NAME = MAXMIN
*  NO DIAGNOSTICS GENERATED
SOURCE ANALYZED
PROGRAM NAME = SPCTRM
*  NO DIAGNOSTICS GENERATED
SOURCE ANALYZED
PROGRAM NAME = MULTI
*  NO DIAGNOSTICS GENERATED
SOURCE ANALYZED
```

```
PROGRAM NAME = MLTPLT
*  NO DIAGNOSTICS GENERATED
SOURCE ANALYZED
PROGRAM NAME = RMS
*  NO DIAGNOSTICS GENERATED
SOURCE ANALYZED
PROGRAM NAME = AVG
*  NO DIAGNOSTICS GENERATED
SOURCE ANALYZED
PROGRAM NAME = SIMULT
*  NO DIAGNOSTICS GENERATED
SOURCE ANALYZED
PROGRAM NAME = LMS
*  NO DIAGNOSTICS GENERATED
SOURCE ANALYZED
PROGRAM NAME = PLT
*  NO DIAGNOSTICS GENERATED
SOURCE ANALYZED
PROGRAM NAME = SOLV
*  NO DIAGNOSTICS GENERATED
    *STATISTICS*  NO DIAGNOSTICS THIS STEP
DISK 'T' NOT ACCESSED.
B (126) R/O
C (127) R/O
E (128) R/O

          ... Your Fortran program is now being loaded ...
                ... execution will soon follow ...
EXECUTION BEGINS...

ENTER EVENT RECORDING NUMBER-I3-
383

EVENT NUMBER 383

383. A33. 10 SEPT81 5KM EOD SHOT. SET B. NO DELAY. C141 ON FINAL
```

```
   AT END OF TAPE."
ENTER SAMPLE RATE IN HERTZ-REAL-
120.
ENTER LOW LOOK ANGLE IN DEGREES-I3-
-100
ENTER HIGH LOOK ANGLE IN DEGREES-I3-
200
ENTER MATCH FILTER THRESHOLD. RANGE OF 0. TO 1.0
.9
ENTER PLOT SCALING FACTOR-REAL-
.85
ENTER NUMBER OF SENSORS IN RING 6 OR 9 ONLY-I1-
9
ENTER SENSOR NUMBER FOR DISPLAY-I1-
4
ENTER NOISE THRESHOLD LEVEL -REAL-
1000.
ENTER DATA WINDOW SIZE FOR DIRECTION FINDING-I4-
0400
FOR COMPRS OUTPUT ENTER -1-. FOR TEK618 ENTER -2-
1
TO CREATE SIMULATED TARGETS ENTER -1- ELSE -2-
1
ENTER THE FOUR SIMULATION FREQUENCIES-REAL-
ENTER FREQUENCY
0
ENTER FREQUENCY
0
```

```
ENTER FREQUENCY
0
ENTER FREQUENCY
120.
ENTER AMPLITUDES FOR EACH FREQUENCY-REAL-
ENTER AMPLITUDE
0
ENTER AMPLITUDE
0
ENTER AMPLITUDE
0
ENTER AMPLITUDE
4000.
ENTER TARGET ANGLE FOR EACH FREQUENCY-I3-
SIX SENSORS ALLOWABLE ANGLES;0,60,120,180,240,300
FOR NINE SENSORS;0,40,80,120,160,200,240,280,320
ENTER ANGLE
0
ENTER ANGLE
0
ENTER ANGLE
0
ENTER ANGLE
120
TO MODIFY AMPLITUDE OF SIGNAL ABOVE NOISE THRESHOLD
ENTER - 1 -,ELSE ENTER - 2 -
```

```
2

ENTER DEGREE OF POLYNOMIAL DESIRED -I1-

FOR SIX SENSORS ENTER 2 - 4, FOR NINE ENTER 2 - 7
4
>> USING A PRE-ALLOCATED DATASET FOR UNIT FT17F001.
>> USING A PRE-ALLOCATED DATASET FOR UNIT FT18F001.

CATALOG AS TARGET? IF YES TYPE - 1 -, ELSE - 2 -
2

FOR MATCH FILTER DIREC FINDING ENTER - 1 - ELSE -2-
1

FOR PHASE DELAY METHOD ENTER -1,FOR LMS ENTER -2
2

ENTER DEGREE OF POLYNOMIAL DESIRED -I1-

FOR SIX SENSORS ENTER 2 - 4, FOR NINE ENTER 2 - 7
4

TO VIEW OTHER SENSORS ENTER - 1 -
1

ENTER - 2 - TO CONTINUE TO NEXT TIME FRAME
2
```

APPENDIX C

PROGRAM LISTING

```
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C                                                                        C
C     PROGRAM MFILTER IS AN INTERACTIVE PROGRAM USED FOR EVALUATION OF   C
C     SEISMIC DATA.  DISCRETE MATCHED FILTERING IS USED TO CLASSIFY      C
C     TARGETS FROM THEIR SEISMIC SIGNATURES.  TARGET DIRECTIONS ARE      C
C     FOUND USING THE RELATIVE MATCHED FILTER PEAK POSITIONS.  THE       C
C     PROGRAM OUTPUTS FOR EACH 1024 SAMPLE PERIOD, THE AMPLITUDE         C
C     VERSUS TIME, POWER VERSUS FREQUENCY, MATCHED FILTER AMPLITUDE      C
C     VERSUS POSITION, AND THE TARGET CLASSES FOUND WITH THEIR RESPEC-   C
C     TIVE DIRECTIONS.  SIMULATION OF SEISMIC TARGETS IS SUPPORTED FOR   C
C     THE VALIDATION OF THE CLASSIFICATION AND DIRECTION ROUTINES.       C
C     SIMULATED TARGET SPECIFICATIONS ARE ENTERED INTERACTIVELY.         C
C     PROMPTING MESSAGES JUST PRIOR TO ALL USER ENTRIES, SPECIFY THE     C
C     TYPE OF ENTRY REQUIRED.  A PROMPT FOR A REAL NUMBER REQUIRES THAT  C
C     A DECIMAL POINT BE INCLUDED IN THE ENTRY.  A PROMPT FOR AN INTEGERC
C     NUMBER SPECIFIES THE NUMBER OF DIGITS REQUIRED I.E., IF -I4- IS    C
C     SPECIFIED AND THE NUMBER TWENTY IS TO BE ENTERED, "0020" MUST BE   C
C     ENTERED.                                                           C
C                                                                        C
C                            GLOBAL VARIABLES                            C
C                            ----------------                            C
C                                                                        C
C     VARIABLE     TYPE      DESCRIPTION                                 C
C     NAME                                                               C
C                            ------------                                C
C     DATA1-9      INTEGER   ARRAYS OF EXPERIMENTAL DATA LOADED FROM A   C
C                            DATA FILE                                   C
C     PWR1-9       REAL      ARRAYS FOR SENSORS RELATIVE SPECTRAL POWERS C
C     CORR,II      INTEGER   SENSOR NUMBER FOR DISPLAY OR ANALYSIS       C
C     IWK          INTEGER   ARRAY USED BY THE FFT ROUTINE               C
C     DIRECT       INTEGER   VALUE OF INITIAL PRIMARY TARGET DIRECTION   C
C     DIRC         REAL      VALUE OF TARGET DIRECTION                   C
C     LOW,HIGH     INTEGER   LOW AND HIGH ANGLES SPECIFYING THE SECTOR   C
C                            FOR TARGETS OF INTEREST                     C
C     C            INTEGER   VALUE SELECTS COMPRS OR TEK618 OUTPUT       C
C                            FOR PLOTS                                   C
C     TESTNO       INTEGER   EVENT NUMBER UNDER ANALYSIS OR TO BE PLOTTEDC
C     COMMEN,      REAL*4    ARRAYS USED FOR INPUT AND OUTPUT OF         C
C     COMM1,                 THE COMMENTS OF THE EXPERIMENTAL EVENT      C
C     COMM2                  UNDER EVALUATION                            C
C     SF           REAL      SAMPLING FREQUENCY                          C
C     DF           REAL      FREQUENCY INCREMENT                         C
C     DT           REAL      TIME INCREMENT                              C
C     XT,XF        REAL      ARRAYS USED IN THE CALCULATION OF THE TIME  C
C                            AND FREQUENCY ARRAY RANGES                  C
C     TIME         REAL      TIME AXIS ARRAY                             C
C     FREQ         REAL      FREQUENCY AXIS ARRAY                        C
C     RA1-9,R1-9   REAL      ARRAYS OF EXPERIMENTAL DATA                 C
```

```
C     B            REAL       ARRAY USED BY LIBRARY ROUTINE                   C
C     IM           REAL       ARRAY OF RELATIVE SENSOR ARRAY ANGLES           C
C     RMAT         REAL       ARRAY USED FOR COMPUTATION AND STORAGE OF       C
C                             MATCHED FILTER OUTPUT                           C
C     UNIT         REAL       ARRAY USED FOR POSITION AXIS IN THE  MATCHEDC
C                             FILTER PLOT                                     C
C     CAT,SCAT     REAL       ARRAY USED FOR STORAGE OF ONE SAMPLE SIGNAL C
C     ECAT,TCAT    REAL       ARRAY CONTAINING ALL FILTER SAMPLE SIGNALS  C
C     RMAG,RA      REAL       ARRAY FOR PASSING ARRAYS RA1-9                  C
C     PWR          REAL       ARRAY FOR PASSING ARRAYS PWR1-9                 C
C     DIR          REAL       ARRAY OF THE DIRECTIONS OF THE TARGET CLASSES
C                             FOUND BY THE MULTIPLE DIRECTION ROUTINE        C
C     FLATE        REAL       ARRAY CONTAINING SEGMENTS OF RMAT              C
C     THRES        REAL       VALUE IS THRESHOLD SPECIFIED FOR MATCHED       C
C                             FILTER DETECTION OF THE FIVE TARGET CLASSES C
C     NUMSEN       INTEGER    NUMBER OF SENSORS IN THE RING                   C
C     V,A,P        REAL       ARRAYS FOR THE FREQUENCY, AMPLITUDE, DIREC- C
C                             TION AND PHASE OF THE SIMULATED TARGETS        C
C     ND           INTEGER    ARRAY OF SIMULATED TARGET DIRECTIONS
C     A1-9         COMPLEX    ARRAYS USED FOR FINDING AND STORING THE        C
C                             FREQUENCY CONTENT OF ARRAYS RA1-9              C
C     SCALE        REAL       SETS THE SIZE OF GRAPHIC OUTPUT                C
C     TS,TF        REAL       FIRST AND LAST VALUE OF THE PLOTTING TIME      C
C                             SCALE                                           C
C     ITRGET       INTEGER    ARRAY OF SENSOR MATCHED FILTER PEAK            C
C                             FOR EACH TARGET TYPE                            C
C     NTYP         INTEGER    ARRAY OF PEAK POSITIONS FOR A TARGET           C
C     JL           INTEGER    SAMPLE PERIOD NUMBER                            C
C     KT,NW        INTEGER    NUMBER OF POINTS USED FOR MATCHED FILTERING C
C     NFRM         INTEGER    TARGET TYPE NUMBER                              C
C     WKAREA       REAL       ARRAY USED BY THE MATRIX SOLVING ROUTINE       C
C     NOR          INTEGER    ORDER OF LEAST MEAN SQUARES POLYNOMIAL         C
C                                                                             C
C                                                                             C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C                                                                             C
      DIMENSION TRIX(9,9),B(9),WKAREA(108)
      INTEGER*2 DATA1(1024),DATA2(1024),DATA3(1024),DATA4(1024),
     1DATA5(1024),DATA6(1024),DATA7(1024),DATA8(1024),
     2DATA9(1024)
      INTEGER IWK(11),IORR,DIRECT,LOW,HIGH,C,TESTAC,
     1NTYP(6),NC(4),NUMSEN,NW,ITRGET(9,5),NTGT(9),NTAR(9)
      REAL*4 COMMEN(16),COMM1(16),COMM2(16)
      REAL SF,F,T,PI,XI(1024),XF(1024),TIME(1024),FREQ(1024),
     1RA1(1024),RA2(1024),RA3(1024),RA4(1024),RA5(1024),
     2RA6(1024),RA7(1024),RA8(1024),RA9(1024),DIR(5),DIRC,
     3PWR1(1024),PWR2(1024),PWR3(1024),PWR4(1024),PWR5(1024),
     4PWR6(1024),PWR7(1024),PWR8(1024),PWR9(1024),
```

```
     5X(5),Y(360),M(9),TH(9),VX(360),TT(5),
     6MAT(11264),UM1(11264),CAT(1024),RMAG(1024),PWR(1024),
     7RA(1024),ICEN(5),
     8PLATE(1024),THRES,XCAT(5120),V(4),A(4),P(9,4)
      COMPLEX A1(1024),A2(1024),A3(1024),A4(1024),A5(1024),
     2A6(1024),A7(1024),A8(1024),A9(1024)
C
C
C     INTERACTIVE INITIALIZATION OF PROGRAM
C
      WRITE(6,79)
79    FORMAT('0','ENTER EVENT RECORDING NUMBER-I3-')
      READ(10,80)TESTNO
80    FORMAT(I3)
      WRITE(6,552)TESTNO
552   FORMAT('0','EVENT NUMBER ',I3)
      DO 777 J = 1,60
         READ(1,559)NLEAD,COMMEN
         READ(1,560)COMM1
         READ(1,560)COMM2
560      FORMAT(16A4)
559      FORMAT(3X,I3,16A4)
         IF((NLEAD).EQ.(TESTNO)) WRITE(6,720)NLEAD,COMMEN
720      FORMAT('0',I3,16A4)
         IF((NLEAD).EQ.(TESTNO)) WRITE(6,721)COMM1
         IF((NLEAD).EQ.(TESTNO)) WRITE(6,721)COMM2
721      FORMAT('0',16A4)
777   CONTINUE
      WRITE (6,47)
47    FORMAT('0','ENTER SAMPLE RATE IN HERTZ-REAL-')
      READ(10,78)SF
78    FORMAT(F4.1)
      WRITE(6,81)
81    FORMAT('0','ENTER LOW LOOK ANGLE IN DEGREES-I3-')
83    FORMAT('0','ENTER HIGH LOOK ANGLE IN DEGREES-I3-')
      READ(10,82)LOW
      WRITE(6,83)
      READ(10,82)HIGH
82    FORMAT(I4)
      WRITE (6,19)
19    FORMAT ('0','ENTER MATCH FILTER THRESHOLD. RANGE OF 0. TO 1.0')
      READ (10,17) THRES
17    FORMAT (F3.2)
      WRITE (6,11)
11    FORMAT('0','ENTER PLOT SCALING FACTOR-REAL-')
      READ(10,22)SCALE
22    FORMAT(F4.2)
      WRITE(6,85)
```

```
85    FORMAT('0','ENTER NUMBER OF SENSORS IN RING 6 OR 9 ONLY-I1-')
      READ(5,15)NUMSEN
      WRITE(6,13)
13    FORMAT('0','ENTER SENSOR NUMBER FOR DISPLAY-I1-')
      READ (5,15)IORA
15    FORMAT(I1)
      WRITE(6,137)
137   FORMAT('0','ENTER NOISE THRESHOLD LEVEL -REAL-')
      READ(5,77)NOISE
77    FORMAT(F5.1)
      WRITE(6,201)
201   FORMAT('0','ENTER DATA WINDOW SIZE FOR DIRECTION FINDING-I4-')
      READ(5,62)NW
      IF((NW).GT.(1024)) NW = 1024
      WRITE(6,138)
138   FORMAT('0','FOR COMPRS OUTPUT ENTER -1-. FOR TEK618 ENTER -2-')
      READ(5,15)C
      WRITE(6,139)
139   FORMAT('0','TO CREATE SIMULATED TARGETS ENTER -1- ELSE -2-')
      READ(5,27)NSIMUL
27    FORMAT(I1)
      REDUCE = 1
      M=10
      N=1024
      N2=N/2
      DIRECT = 0
      F=SF/FLOAT(N)
      T=1./SF
      PI=3.141593
      DO 333 JIM =1,6
      NTYP(JIM) = 3
333   CONTINUE
C
C     LOAD FILTER SAMPLE SIGNAL ARRAY FROM DATA FILE
C
      DO 88 IJ = 4,512,4
         READ(4,633) BCAT(IJ - 3),BCAT(IJ - 2),BCAT(IJ - 1),BCAT(IJ)
633   FORMAT(3X,F6.2,3X,F6.2,3X,F6.2,3X,F6.2)
88    CONTINUE
C
C     CALCULATE TIME AND FREQUENCY RANGES.
C     THE VALUE FOR -JL- ALSO DENOTES THE TIME PERIOD OF THE SENSOR DATA
C     E.G., JL = 1 MAY MEAN 0 - 8 SECONDS, JL = 2 MAY MEAN 8 - 16 SECONDS
C     ETC.
C
      DO 876 IQ = 1,4
      V(IQ) = 0.
      NO(IQ) = 0
```

```
      A(IG) = 0.
876   CONTINUE
      DO 10 JUMP = 1,4
      JL = JUMP
      DO 20 J=1,1024
         XT(J)=FLOAT(J)
         XF(J)=FLOAT(J)
         TIME(J)=XT(J)*T + (JL - 1)*1024*T
         FREQ(J)=XF(J)*F
20    CONTINUE
C
C
C    LOAD THE SENSOR DATA ARRAYS WITH THEIR RESPECTIVE DATA FOR THE TIME
C    PERIOD
C
      DO 100 I = 10,1020,10
         READ(5,7)DATA1(I - 9),DATA1(I - 8),DATA1(I - 7),DATA1(I - 6),
     1DATA1(I - 5),DATA1(I - 4),DATA1(I - 3),DATA1(I - 2),
     2DATA1(I - 1),DATA1(I)
100   CONTINUE
7     FORMAT(I6,I6,I6,I6,I6,I6,I6,I6,I6,I6)
      DO 110 I = 10,1020,10
         READ(5,7)DATA2(I - 9),DATA2(I - 8),DATA2(I - 7),DATA2(I - 6),
     1DATA2(I - 5),DATA2(I - 4),DATA2(I - 3),DATA2(I - 2),
     2DATA2(I - 1),DATA2(I)
110   CONTINUE
      DO 120 I = 10,1020,10
         READ(5,7)DATA3(I - 9),DATA3(I - 8),DATA3(I - 7),DATA3(I - 6),
     1DATA3(I - 5),DATA3(I - 4),DATA3(I - 3),DATA3(I - 2),
     2DATA3(I - 1),DATA3(I)
120   CONTINUE
      DO 130 I = 10,1020,10
         READ(5,7)DATA4(I - 9),DATA4(I - 8),DATA4(I - 7),DATA4(I - 6),
     1DATA4(I - 5),DATA4(I - 4),DATA4(I - 3),DATA4(I - 2),
     2DATA4(I - 1),DATA4(I)
130   CONTINUE
      DO 140 I = 10,1020,10
         READ(5,7)DATA5(I - 9),DATA5(I - 8),DATA5(I - 7),DATA5(I - 6),
     1DATA5(I - 5),DATA5(I - 4),DATA5(I - 3),DATA5(I - 2),
     2DATA5(I - 1),DATA5(I)
140   CONTINUE
      DO 150 I = 10,1020,10
         READ(5,7)DATA6(I - 9),DATA6(I - 8),DATA6(I - 7),DATA6(I - 6),
     1DATA6(I - 5),DATA6(I - 4),DATA6(I - 3),DATA6(I - 2),
     2DATA6(I - 1),DATA6(I)
150   CONTINUE
      IF((NUMSEN).EQ.(6)) GO TO 181
      DO 160 I = 10,1020,10
         READ(5,7)DATA7(I - 9),DATA7(I - 8),DATA7(I - 7),DATA7(I - 6),
```

```
     1DATA7(I - 5),DATA7(I - 4),CATA7(I - 3),CATA7(I - 2),            MF102410
     2DATA7(I - 1),DATA7(I)                                            MF102420
 160  CONTINUE                                                          MF102430
      DO 170 I = 10,1C20,10                                             MF102440
         READ(5,7)DATA8(I - 9),DATA8(I - 8),DATA8(I - 7),DATA8(I - 6), MF102450
     1DATA8(I - 5),DATA8(I - 4),CATA8(I - 3),CATA8(I - 2),            MF102460
     2DATA8(I - 1),DATA8(I)                                            MF102470
 170  CONTINUE                                                          MF102480
      DO 180 I = 10,1020,10                                             MF102490
         READ(5,7)DATA9(I - 9),DATA9(I - 8),DATA9(I - 7),DATA9(I - 6), MF102500
     1DATA9(I - 5),DATA9(I - 4),DATA9(I - 3),CATA9(I - 2),            MF102510
     2DATA9(I - 1),DATA9(I)                                            MF102520
 180  CONTINUE                                                          MF102530
C                                                                       MF102540
C    CONVERT THE INTEGER DATA TO REAL AND COMPLEX VALUES                MF102550
C                                                                       MF102560
 181  CALL MYDATA(TIME,DATA1,N,RA1,A1)                                  MF102570
      CALL MYDATA(TIME,DATA2,N,RA2,A2)                                  MF102580
      CALL MYDATA(TIME,DATA3,N,RA3,A3)                                  MF102590
      CALL MYDATA(TIME,DATA4,N,RA4,A4)                                  MF102600
      CALL MYDATA(TIME,DATA5,N,RA5,A5)                                  MF102610
      CALL MYDATA(TIME,DATA6,N,RA6,A6)                                  MF102620
      IF(NUMSEN.EQ.(6)) GO TO 86                                        MF102630
      CALL MYDATA(TIME,DATA7,N,RA7,A7)                                  MF102640
      CALL MYDATA(TIME,DATA8,N,RA8,A8)                                  MF102650
      CALL MYDATA(TIME,DATA9,N,RA9,A9)                                  MF102660
C                                                                       MF102670
C    IF SIMULATION IS REQUESTED, CALL THE SIMULATION ROUTINE            MF102680
C                                                                       MF102690
 86   IF(INSIMUL.EQ.(1)) CALL SIMULT(RA1,RA2,RA3,RA4,RA5,RA6,           MF102700
     1RA7,RA8,RA9,A1,A2,A3,A4,A5,A6,A7,A8,A9,V,A,ND,TNOISE,TIME,JL,P,   MF102710
     2REDUCE,NUMSEN)                                                    MF102720
C                                                                       MF102730
C    CALCULATE THE FFT AND SPECTRAL FREQUENCY POWER FOR EACH SENSORS DATA MF102740
C                                                                       MF102750
      CALL FFT2C(A1,M,IWK)                                              MF102760
      CALL SPCTRM(TIME,RA1,FREQ,A1,N,PWR1,PDB1,PH1)                     MF102770
C                                                                       MF102780
      CALL FFT2C(A2,M,IWK)                                              MF102790
      CALL SPCTRM(TIME,RA2,FREQ,A2,N,PWR2,PDB2,PH2)                     MF102800
C                                                                       MF102810
      CALL FFT2C(A3,M,IWK)                                              MF102820
      CALL SPCTRM(TIME,RA3,FREQ,A3,N,PWR3,PDB3,PH3)                     MF102830
C                                                                       MF102840
      CALL FFT2C(A4,M,IWK)                                              MF102850
      CALL SPCTRM(TIME,RA4,FREQ,A4,N,PWR4,PDB4,PH4)                     MF102860
C                                                                       MF102870
      CALL FFT2C(A5,M,IWK)                                              MF102880
```

```
      CALL SPCTRM(TIME,RA5,FREQ,A5,N,PWR5,PDE5,PH5)
C
      CALL FFT2C(A6,M,IWK)
      CALL SPCTRM(TIME,RA6,FREQ,A6,N,PWR6,PDE6,PH6)
C
      IF((NUMSEN).EQ.(6)) GO TO 87
      CALL FFT2C(A7,M,IWK)
      CALL SPCTRM(TIME,RA7,FREQ,A7,N,PWR7,PDE7,PH7)
C
      CALL FFT2C(A8,M,IWK)
      CALL SPCTRM(TIME,RA8,FREQ,A8,N,PWR8,PDE8,PH8)
C
      CALL FFT2C(A9,M,IWK)
      CALL SPCTRM(TIME,RA9,FREQ,A9,N,PWR9,PDE9,PH9)
C
C    DETERMINE IF A TARGET IS PRESENT AND IF THERE IS, IS IT IN THE
C    SECTOR OF INTEREST.
C
C
87    CALL MAXMIN(RA1,1024,K,RAGMAX,L,RIN)
      IF((ABS(RAGMAX)).GT.(TNOISE)) CALL ANGLE(DIRC,RA1,RA2,RA3,RA4,
     1RA5,RA6,RA7,RA8,RA9,NUMSEN,TESTNO,TIME,C,SCALE,NTAR)
      IF(((LOW).GT.(DIRECT)).OR.((HIGH).LT.(DIRECT))) GO TO 10
      CALL LPS (NTAR,DIRC,NUMSEN,C,SCALE,TESTNO,TIME,O,Y,VX,X,TT,INDEX,
     1NOR,TRIX,BINKAREA)
      NFRM = 0
      IF((NTAR(1)).GT.(0))CALL PLT(C,SCALE,TESTNO,NUMSEN,TIME,
     1Y,VX,X,TT,INDEX,NOR,DIRC,NFRM)
      DIRECT = IFIX(DIRC)
C
C    FOR THE SELECTED SENSOR IF A TARGET IS PRESENT, OUTPUT THE MATCHED
C    FILTER RESPONSE, THE AMPLITUDE VERSUS TIME AND THE
C    SPECTRAL ECHEE VERSUS FREQUENCY PLOTS. IF SELECTED, OUTPUT THE
C    MULTIPLE TARGET INFORMATION.
C
99     IF((ICERR).NE.(1)) GO TC 444
      CALL MAXMIN(RA1,1024,K,RAGMAX,L,RIN)
      IF((ABS(RAGMAX)).GT.(TNOISE)) GC TC 111
      WRITE(6,112)
      GO TO 444
112   FORMAT('0','NO DETECTABLE TARGET')
111   CALL MATCH(RA1,NTYP,SCALE,IORR,DIRECT,THRES,BLAT,TESTNO,JL,C,N,
     1TS,TF,TIME)
      CALL TIMPLT(TIME,RA1,DIRECT,SCALE,ICRR,NTYP,TESTNO,TS,TF,C)
      CALL FREQOT(FREQ,PWR1,DIRECT,SCALE,IORR,NTYP,TESTNO,TS,TF,C)
C
C
C
C
444   IF((IOFF).NE.(2)) GC TC 445
```

```
      CALL MAXMIN(RA2,1024,K,RAGMAX,L,RIN)
      IF((ABS(RAGMAX)).GT.(TNOISE)) GO TO 113
      WRITE(6,112)
      GO TO 445
113   CALL MATCH(RA2,NTYP,SCALE,ICRR,DIRECT,THRES,BCAT,TESTNO,JL,C,N,
     1TS,TF,TIME)
      CALL TIMOUT(TIME,RA2,DIRECT,SCALE,ICRR,NTYP,TESTNO,TS,TF,C)
      CALL FREQOT(FREC,PWR2,DIRECT,SCALE,IORR,NTYP,TESTNO,TS,TF,C)
C
C
C
445   IF((IORR).NE.(3)) GO TO 446
      CALL MAXMIN(RA3,1024,K,RAGMAX,L,RIN)
      IF((ABS(RAGMAX)).GT.(TNOISE)) GO TO 114
      WRITE(6,112)
      GO TO 446
114   CALL MATCH(RA3,NTYP,SCALE,IORR,DIRECT,THRES,BCAT,TESTNO,JL,C,N,
     1TS,TF,TIME)
      CALL TIMOUT(TIME,RA3,DIRECT,SCALE,ICRR,NTYP,TESTNO,TS,TF,C)
      CALL FREQOT(FREC,PWR3,DIRECT,SCALE,IORR,NTYP,TESTNO,TS,TF,C)
C
C
C
446   IF((IORR).NE.(4)) GO TO 447
      CALL MAXMIN(RA4,1024,K,RAGMAX,L,RIN)
      IF((ABS(RAGMAX)).GT.(TNOISE)) GO TO 115
      WRITE(6,112)
      GO TO 447
115   CALL MATCH(RA4,NTYP,SCALE,ICRR,DIRECT,THRES,BCAT,TESTNO,JL,C,N,
     1TS,TF,TIME)
      CALL TIMOUT(TIME,RA4,DIRECT,SCALE,ICRR,NTYP,TESTNO,TS,TF,C)
      CALL FREQOT(FREC,PWR4,DIRECT,SCALE,IORR,NTYP,TESTNO,TS,TF,C)
C
C
C
447   IF((IORR).NE.(5)) GO TO 448
      CALL MAXMIN(RA5,1024,K,RAGMAX,L,RIN)
      IF((ABS(RAGMAX)).GT.(TNOISE)) GO TO 116
      WRITE(6,112)
      GO TO 448
116   CALL MATCH(RA5,NTYP,SCALE,IORR,DIRECT,THRES,BCAT,TESTNO,JL,C,N,
     1TS,TF,TIME)
      CALL TIMOUT(TIME,RA5,DIRECT,SCALE,ICRR,NTYP,TESTNO,TS,TF,C)
      CALL FREQOT(FREC,PWR5,DIRECT,SCALE,IORR,NTYP,TESTNO,TS,TF,C)
C
C
C
448   IF((IORR).NE.(6)) GO TO 449
```

```
      CALL MAXMIN(RA6,1024,K,RAGMAX,L,RIN)                              MF03850
      IF((ABS(RAGMAX)).GT.(TNOISE)) GO TO 117                           MF03860
      WRITE(6,112)                                                      MF03870
      GO TO 449                                                         MF03880
117   CALL MATCH(RA6,NTYP,SCALE,IORR,DIRECT,THRES,BCAT,TESTNO,JL,C,N,   MF03890
     1TS,TF,TIME)                                                       MF03900
      CALL TIPOUT(TIME,RA6,DIRECT,SCALE,IORR,NTYP,TESTNO,TS,TF,C)       MF03910
      CALL FRECOT(FREC,PWR6,DIRECT,SCALE,IORR,NTYP,TESTNO,TS,TF,C)      MF03920
C                                                                       MF03930
C                                                                       MF03940
C                                                                       MF03950
449   IF((IORR).NE.(7)) GO TO 450                                       MF03960
      CALL MAXMIN(RA7,1024,K,RAGMAX,L,RIN)                              MF03970
      IF((ABS(RAGMAX)).GT.(TNOISE)) GO TO 118                           MF03980
      WRITE(6,112)                                                      MF03990
      GO TO 450                                                         MF04000
118   CALL MATCH(RA7,NTYP,SCALE,IORR,DIRECT,THRES,BCAT,TESTNO,JL,C,N,   MF04010
     1TS,TF,TIME)                                                       MF04020
      CALL TIPOUT(TIME,RA7,DIRECT,SCALE,IORR,NTYP,TESTNO,TS,TF,C)       MF04030
      CALL FRECOT(FREC,PWR7,DIRECT,SCALE,IORR,NTYP,TESTNO,TS,TF,C)      MF04040
C                                                                       MF04050
C                                                                       MF04060
C                                                                       MF04070
450   IF((IORR).NE.(8)) GO TO 451                                       MF04080
      CALL MAXMIN(RA8,1024,K,RAGMAX,L,RIN)                              MF04090
      IF((ABS(RAGMAX)).GT.(TNOISE)) GO TO 119                           MF04100
      WRITE(6,112)                                                      MF04110
      GO TO 451                                                         MF04120
119   CALL MATCH(RA8,NTYP,SCALE,IORR,DIRECT,THRES,BCAT,TESTNO,JL,C,N,   MF04130
     1TS,TF,TIME)                                                       MF04140
      CALL TIPOUT(TIME,RA8,DIRECT,SCALE,IORR,NTYP,TESTNO,TS,TF,C)       MF04150
      CALL FRECOT(FREC,PWR8,DIRECT,SCALE,IORR,NTYP,TESTNO,TS,TF,C)      MF04160
C                                                                       MF04170
C                                                                       MF04180
C                                                                       MF04190
451   IF((IORR).NE.(9)) GO TO 452                                       MF04200
      CALL MAXMIN(RA9,1024,K,RAGMAX,L,RIN)                              MF04210
      IF((ABS(RAGMAX)).GT.(TNOISE)) GO TO 125                           MF04220
      WRITE(6,112)                                                      MF04230
      GO TO 452                                                         MF04240
125   CALL MATCH(RA9,NTYP,SCALE,IORR,DIRECT,THRES,BCAT,TESTNO,JL,C,N,   MF04250
     1TS,TF,TIME)                                                       MF04260
      CALL TIPOUT(TIME,RA9,DIRECT,SCALE,IORR,NTYP,TESTNO,TS,TF,C)       MF04270
      CALL FRECOT(FREC,PWR9,DIRECT,SCALE,IORR,NTYP,TESTNO,TS,TF,C)      MF04280
C                                                                       MF04290
C                                                                       MF04300
C                                                                       MF04310
452    IF((ABS(RAGMAX)).LT.(TNOISE)) GO TO 454                          MF04320
```

```
      WRITE(6,837)
837   FORMAT('0','FOR MATCH FILTER DIREC FINDING ENTER - 1 - ELSE -2-')
      READ(10,15) MNY
      IF((MNY).EQ.(1))CALL MULTI(RA1,RA2,RA3,RA4,RA5,RA6,RA7,RA8,
     1RA9,NTYP,SCALE,IORR,THRES,BCAT,TESTNO,JL,C,TS,TF,V,A,ND,
     2NW,NUMSEN,TIME,ITRGET,DIRECT,DIR,DIRC)
      IF((MNY).NE.(1)) GO TO 454
      WRITE(6,44)
44    FORMAT('0','FOR PHASE DELAY METHOD ENTER -1,FOR LMS ENTER -2')
      READ(10,393)NGL
393   FORMAT(I1)
      DO 666 I21 = 1,9
         NTAR(I21) = 0
666   CONTINUE
      IF((NGL).EQ.(1))GO TO 101
      DO 678 IW = 1,5
       NTAR(1) = ITRGET(1,IW)
       NTAR(2) = ITRGET(2,IW)
       NTAR(3) = ITRGET(3,IW)
       NTAR(4) = ITRGET(4,IW)
       NTAR(5) = ITRGET(5,IW)
       NTAR(6) = ITRGET(6,IW)
       IF(NUMSEN.EQ.6) GO TO 646
       NTAR(7) = ITRGET(7,IW)
       NTAR(8) = ITRGET(8,IW)
       NTAR(9) = ITRGET(9,IW)
646    NG = IW
       IF((NTAR(1)).EQ.(0)) GO TO 678
      CALL LMS (NTAR,DIRC,NUMSEN,C,SCALE,TESTNO,TIME,NG,Y,
     1VX,X,TT,INDEX,NOR,TRIX,B,WKAREA)
      CALL PLT(C,SCALE,TESTNO,NUMSEN,TIME,Y,VX,X,TT,INDEX,NOR,DIRC,
     1NG)
        DIR(NG) = DIRC
678     CONTINUE
      GO TO 601
C
C    PHASE DELAY METHOD
C
101   DO 60  J3 = 1,5
        TC = 0
        DO 70 K3 = 1,NUMSEN
          TCEN(K3) = FLOAT(ITRGET(K3,J3))
          TC = FLOAT(ITRGET(K3,J3)) + TC
70      CONTINUE
        TC = TC/FLOAT(NUMSEN)
        CE = 0.
        DIVIDE = 0.
        DO 840 N = 1,NUMSEN
```

```
      DO 90 M = 1,NUMSEN
        IF((M).LE.(N)) GO TO 90
        BB = ((TC - TCEN(M))*X(N) - (TC - TCEN(N))*X(M))
        AA= (TC - TCEN(N))*Y(M) - (TC - TCEN(M))*Y(N)
        IF((AA).EQ.(0)) GO TO 90
        IF((BB).LT.(.000001)) GO TO 90
        DIVIDE = DIVIDE + 1.
        CE = ATAN(BB/AA) + QB
 90     CONTINUE
 840   CONTINUE
      NUM = NUMSEN - 1
      QB = (CE/(DIVIDE))*(180.0/3.141593)
      DIR(J3) = CB
 60   CONTINUE
C
 601  CALL MLTPLT(C,SCALE,TESTNO,TS,TF,DIR,V,A,ND,ITRGET)
C
C    SELECT TO EVALUATE OTHER SENSORS IN THIS TIME PERIOD OR CONTINUE
C    TO THE NEXT TIME PERIOD
C
 454  WRITE(6,51)
      WRITE(6,52)
 51   FORMAT('0','TO VIEW OTHER SENSORS ENTER - 1 - ')
 52   FORMAT('0','ENTER - 2 - TO CONTINUE TO NEXT TIME FRAME')
      READ(10,551)NS
 551  FORMAT(I1)
      IF((NS).NE.(1)) GO TO 10
      WRITE(6,57)
 57   FORMAT('0','ENTER NEW SENSOR NUMBER FOR DISPLAY-I1-')
      READ (10,551)ICRR
      GO TO 55
 10    CONTINUE
      CALL DONEPL
      STOP
      END
C
C    SUBROUTINE ANGLE COMPUTES A ROUGH DIRECTION TO THE PRIMARY TARGET
C    FOR USE IN DETERMINING WHETHER THE TARGET IS IN
C    THE SECTOR OF INTEREST
C    TIME DOMAIN ANALYSIS IS USED.
C
       SUBROUTINE ANGLE (DIRC,R1,R2,R3,R4,R5,R6,R7,R8,R9,NUMSEN,TESTNO,
     1TIME,C,SCALE,NTAR)
      INTEGER M(9),TESTNO,NTAR(9),NUMSEN,C
      REAL R1(1024),R2(1024),R3(1024),R4(1024),R5(1024),R6(1024),
     1R7(1024),R8(1024),R9(1024),TIME(1024),DIR(5),DIRC
      DO 12 I = 1,9
        NTAR(I) = 0
```

```
12    CONTINUE                                                            MFI05290
      CALL MAXMIN(R1,1024,M(1),RMAX,L,RMIN)                               MFI05300
      CALL MAXMIN(R2,1024,M(2),RMAX,L,RMIN)                               MFI05310
      CALL MAXMIN(R3,1024,M(3),RMAX,L,RMIN)                               MFI05320
      CALL MAXMIN(R4,1024,M(4),RMAX,L,RMIN)                               MFI05330
      CALL MAXMIN(R5,1024,M(5),RMAX,L,RMIN)                               MFI05340
      CALL MAXMIN(R6,1024,M(6),RMAX,L,RMIN)                               MFI05350
      IF((NUMSEN).EQ.(6)) GO TO 10                                        MFI05360
      CALL MAXMIN(R7,1024,M(7),RMAX,L,RMIN)                               MFI05370
      CALL MAXMIN(R8,1024,M(8),RMAX,L,RMIN)                               MFI05380
      CALL MAXMIN(R9,1024,M(9),RMAX,L,RMIN)                               MFI05390
10    DO 11 I2 = 1,NUMSEN                                                 MFI05400
        NTAR(I2) = M(I2)                                                  MFI05410
11    CONTINUE                                                            MFI05420
      RETURN                                                              MFI05430
      END                                                                 MFI05440
C                                                                         MFI05450
C    SUBROUTINE TIMOUT PLOTS AMPLITUDE VERSUS TIME FOR THE SELECTED       MFI05460
C    SENSOR                                                               MFI05470
C                                                                         MFI05480
      SUBROUTINE TIMOUT (TIME,RA,DIRECT,SCALE,IORR,NTYP,TESTNO,TS,TF,     MFI05490
     1C)                                                                  MFI05500
      REAL RA(1024),TIME(1024)                                            MFI05510
      INTEGER NTYP(6),C,NY,DIRECT,TESTNO                                  MFI05520
      IF((C).EQ.(1)) CALL COMPRS                                          MFI05530
      IF((C).NE.(1)) CALL TEK618                                          MFI05540
      CALL PAGE(11.0,8.5)                                                 MFI05550
      CALL NOBRDR                                                         MFI05560
      CALL BLOWUP(SCALE)                                                  MFI05570
      CALL AREA2D(9.0,6.0)                                                MFI05580
      CALL FRAME                                                          MFI05590
      CALL XNAME('TIME -SECONDS-',14)                                     MFI05600
      CALL YNAME('INPUT',5)                                               MFI05610
      CALL HEADIN('SENSOR INPUT - VS - TIME',24,2.0,1)                    MFI05620
      CALL MESSAG('SENSOR NUMBER ',14,2.0,5.5)                            MFI05630
      CALL INTNO(IORR,4.0,5.5)                                            MFI05640
      CALL MESSAG('EVENT NUMBER',12,2.0,5.7)                              MFI05650
      CALL INTNO(TESTNO,4.0,5.7)                                          MFI05660
      CALL MESSAG('TARGET I.D.',11,2.0,5.3)                               MFI05670
      XPOS = 2.80                                                         MFI05680
      IF((NTYP(1)).NE.(0)) XPOS = XPOS + 1.2                              MFI05690
      IF((NTYP(1)).NE.(0))                                                MFI05700
     1CALL MESSAG('TRKD-VEH',8,XPOS,5.3)                                  MFI05710
      IF((NTYP(2)).NE.(0)) XPOS = XPOS + 1.2                              MFI05720
      IF((NTYP(2)).NE.(0))                                                MFI05730
     1CALL MESSAG('WHLD-VEH',8,XPOS,5.3)                                  MFI05740
      IF((NTYP(3)).NE.(0)) XPOS = XPOS + 1.2                              MFI05750
      IF((NTYP(3)).NE.(0))                                                MFI05760
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```
     1CALL MESSAG('SHL-BLST',8,XPOS,5.3)
      IF((NTYP(4)).NE.(0)) XPOS = XPOS + 1.2
      IF((NTYP(4)).NE.(0))
     1CALL MESSAG('HELICPTR',8,XPOS,5.3)
      IF((NTYP(5)).NE.(0)) XPOS = XPOS + 1.2
      IF((NTYP(5)).NE.(0))
     1CALL MESSAG('PERSONNEL',9,XPOS,5.3)
      CALL MESSAG('INIT DIRECTION',14,2.0,5.1)
      CALL INTNO(DIRECT,4.0,5.1)
      CALL INTAXS
      CALL YAXANG (0.)
      CALL XTICKS(10)
      CALL YTICKS(10)
      TS = FLOAT(IFIX(TIME(1)))
      TF = FLOAT(IFIX(TIME(1024) + 1.))
      CALL MAXMIN(RA,1024,K,RAMAX,L,RAMIN)
      IAMP = 1
      DO 337 NI = 100,5000,100
        IF((IAMP).NE.(1)) GO TO 337
        IF((NI).GE.(ABS(RAMAX))) IAMP = NI
337   CONTINUE
      STEP = IAMP/5.0
      CALL GRAF(TS,1.,TF,FLOAT(-IAMP),STEP,FLOAT(IAMP))
      CALL CURVE(TIME,RA,1024,0.)
      CALL ENDPL(0)
      WRITE(6,70)
70    FORMAT('0','CATALOG AS TARGET? IF YES TYPE - 1 -, ELSE - 2 -')
      READ(10,71)NY
71    FORMAT(I1)
C
C     SEISMIC DATA DESIRED TO BE USED AS A SAMPLE SIGNAL IN THE MATCHED
C     FILTER CAN BE STORED IN THE FILTER DATA FILE.
C
      IF((NY).NE.(1)) GO TO 45
      DO 44 JJ = 4,1024,4
      IF((ABS(RA(JJ))).LT.(.001)) RA(JJ) = 0
      IF((ABS(RA(JJ - 1))).LT.(.001)) RA(JJ - 1) = 0
      IF((ABS(RA(JJ -2))).LT.(.001)) RA(JJ - 2) = 0
      IF((ABS(RA(JJ -3))).LT.(.001)) RA(JJ - 3) = 0
      WRITE (4,3)RA(JJ -3),RA(JJ -2),RA(JJ -1),RA(JJ)
3     FORMAT(3X,F9.2,3X,F9.2,3X,F9.2,3X,F9.2)
44    CONTINUE
45    RETURN
      END
C
C     SUBROUTINE FREQOT PLOTS SPECTRAL POWER VERSUS FREQUENCY
C
      SUBROUTINE FREQOT(FREQ,PWR,DIRECT,SCALE,IORF,NTYP,TESTNO,TS,TF,
```

```
 1C)
 REAL PWR(1024),FREQ(1024)
 INTEGER NTYP(6),C,DIRECT,TESTNO
 IF((C).EQ.(1)) CALL COMPRS
 IF((C).NE.(1)) CALL TEK618
 CALL PAGE(11.0,8.5)
 CALL NOBRDR
 CALL BLOWUP(SCALE)
 CALL AREA2D(9.0,6.0)
 CALL FRAME
 CALL XNAME('FREQUENCY -HZ-',14)
 CALL YNAME('POWER',5)
 CALL HEADIN('SENSOR POWER -VS- FREQUENCY',27,2.0,1)
 CALL MESSAG('EVENT NUMBER ',13,2.0,5.7)
 CALL INTNO(TESTNO,4.0,5.7)
 CALL MESSAG('SENSOR NUMBER ',14,2.0,5.5)
 CALL INTNO(IORR,4.0,5.5)
 CALL MESSAG('TARGET I.D.',11,2.0,5.3)
 XPOS = 2.80
 IF((NTYP(1)).NE.(0)) XPOS = XPOS + 1.2
 IF((NTYP(1)).NE.(0))
1CALL MESSAG('TRKD-VEH',8,XPOS,5.3)
 IF((NTYP(2)).NE.(0)) XPOS = XPOS + 1.2
 IF((NTYP(2)).NE.(0))
1CALL MESSAG('WHLD-VEH',8,XPOS,5.3)
 IF((NTYP(3)).NE.(0)) XPOS = XPOS + 1.2
 IF((NTYP(3)).NE.(0))
1CALL MESSAG('SHL-BLST',8,XPOS,5.3)
 IF((NTYP(4)).NE.(0)) XPOS = XPOS + 1.2
 IF((NTYP(4)).NE.(0))
1CALL MESSAG('HELICPTR',8,XPOS,5.3)
 IF((NTYP(5)).NE.(0)) XPOS = XPOS + 1.2
 IF((NTYP(5)).NE.(0))
1CALL MESSAG('PERSONNEL',9,XPOS,5.3)
 CALL MESSAG('INIT DIRECTION',14,2.0,5.1)
 CALL INTNO(DIRECT,4.0,5.1)
 CALL MESSAG('TIME PERIOD(SEC)',16,2.0,4.9)
 CALL REALNO(TS,2,3.9,4.9)
 CALL REALNO(TF,2,4.7,4.9)
 XMAX = 1.0
 DO 39 I = 20,500,20
     IF((XMAX).NE.(1.0)) GO TO 39
     IF((I).GE.(IFIX(FREQ(512)))) XMAX = FLOAT(I)
39 CONTINUE
 XSTEP = XMAX/4.00
 CALL MAXMIN(PWR,1024,KP,PWRMAX,LP,PWRMIN)
 NS = IFIX(XSTEP)
 IF((XSTEP).GT.(20.0)) NS = IFIX(FLOAT(NS)/10.0)
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```
      CALL INTAXS
      CALL YAXANG (0.)
      CALL XTICKS(NS)
      CALL YTICKS(10)
      CALL GRAF(0.,XSTEP,XMAX,0.,.1,PWRMAX)
      CALL CURVE(FREQ,PWR,512,0.)
      CALL RESET ('ALL')
      CALL ENDPL(0)
38    CONTINUE
37    RETURN
      END
C
C    SUBROUTINE MATCH PERFORMS THE MATCHED FILTERING OF THE SELECTED
C    SENSORS DATA.  TARGET CLASSIFICATIONS FOUND ARE RETURNED, AS ARE
C    THEIR RESPECTIVE PEAK SIGNAL DETECTION POSITIONS.
C
      SUBROUTINE MATCH(RMAG,NTYP,SCALE,IERR,DIRECT,THRES,TCAT,TESTNO,
     1JL,C,NT,TS,TF,TIME)
      REAL RMAG(NT),CAT(1024),UNIT(11264),PLATE(2048),SCAT(1024),
     1RMAT(11264),THRES,XRAY4(2),YRAY(2),TIME(1024),
     2XRAY1(2),XRAY2(2),XRAY3(2),TCAT(5120)
      INTEGER NTYP(6),C,DIRECT,TESTNO
C
      DATA XRAY1/2048.,2048./
      DATA XRAY2/4096.,4096./
      DATA XRAY3/6144.,6144./
      DATA XRAY4/8192.,8192./
      DATA YRAY/-1.0,1.0/
      DO 33 J = 1,1024
         PLATE(J) = 0.
         PLATE(J + 1024) = 0.
         SCAT(J) = 0.
         CAT(J) = 0.
33    CONTINUE
      NH = NT/2
      N2 = NT*2
      N4 = NT*4
      N6 = NT*6
      N8 = NT*8
      N10 = NT*10
      N11 = NT*11
      DO 600 MM = 1,N11
      RMAT(MM) = 0.0
      UNIT(MM) = MM
600   CONTINUE
      DO 201 K = N2,N10,N2
      NM = K - NT
       DO 202 KK = 1,NT
```

```
      RMAT(NM + KK) = RMAG(KK)
202   CONTINUE
201   CONTINUE
      NTYP(1) = 0
      NTYP(2) = 0
      NTYP(3) = 0
      NTYP(4) = 0
      NTYP(5) = 0
C
C    NEW FILTER SAMPLE SIGNALS ARE LOADED AFTER EACH SUCCESSIVE 2048
C    ELEMENTS OF THE WORKING ARRAY 'RMAT' ARE CONVOLVED
C
111   DO 400 I =1,N10
      IF(((I).EQ.(1)).OR.((I).EQ.(N2)).OR.((I).EQ.(N4)).OR.
     1((I).EQ.(N6)).OR.((I).EQ.(N8)))
     2GO TO 98
      GO TO 99
98    IF((I).EQ.(1)) MARK = 1025
      IF((I).EQ.(N2)) MARK = 2049
      IF((I).EQ.(N4)) MARK = 3073
      IF((I).EQ.(N6)) MARK = 4097
      IF((I).EQ.(N8)) MARK = 5121
C
C    FILTER DATA REVERSED
C
      DO 777 LL = 1,NT
      CAT(LL) = TCAT(-LL + MARK)
777   CONTINUE
C
C    EXECUTION TIME MAY BE REDUCED BY SELECTING SMALLER WINDOWS OR
C    SEGMENTS AROUND THE PEAK AMPLITUDES OF THE FILTER AND SEISMIC DATA
C
      CALL MAXMIN(CAT,1024,LL,CATM,KK,CATMIN)
      DO 10 II = 1,NT
        IF((LL - NH).LE.(0)) LL = NH
        IF((LL).GT.(1024 - NH)) LL = 1024 - NH
        SCAT(II) = CAT(II - NH + LL)
10     CONTINUE
99    CALL RMS(SCAT,NT,CATMAX)
      CALL RMS(RMAG,NT,RAGMAX)
      CALL AVG(SCAT,NT,ACAT)
      RMAT(I) = 0
C
C   REMOVAL OF DC BIAS AND NORMALIZATION OF THE FILTER AND SEISMIC DATA
C
        DO 200 KN = 1,NT
        IF(((CATMAX).EQ.(0)).OR.((RAGMAX).EQ.(0))) GO TO 200
C
```

```
C     DISCRETE CONVOLUTION PREFORMED
C
        RMAT(I) = ((RMAT(I + KN))/(ABS(RAGMAX)))*
       1((SCAT(KN) - ACAT)/(CATMAX)) + RMAT(I)
200     CONTINUE
400     CONTINUE
        CALL MAXMIN(RMAT,N11,LZ,RATMAX,KZ,RATMIN)
        DO 390 NN = 1,N11
        IF((RATMAX).EQ.(0)) GO TO 390
        RMAT(NN) = RMAT(NN)/(ABS(RATMAX))
390     CONTINUE
C
C     CLASSIFICATION OF TARGETS BY TARGET TYPE
C
        DO 302 J1 = N2,N10,N2
           DO 301 I1 = 1,N2
              PLATE(I1) = RMAT(J1 - N2 + I1)
301        CONTINUE
           CALL MAXMIN(PLATE,N2,LP,PMAX,LS,PMIN)
           IF((ABS(PMAX)).GE.(THRES)) NTYP(J1/N2) = LP
302     CONTINUE
C
C     MATCHED FILTER OUTPUT PLOTTING
C
        IF((IORR).EQ.(0)) GO TO 391
        IF((C).EQ.(1)) CALL COMPRS
        IF((C).NE.(1)) CALL TEK618
        CALL PAGE(11.0,8.5)
        CALL NOBRDR
        CALL BLOWUP(SCALE)
        CALL AREA2D(9.0,6.0)
        CALL FRAME
        CALL XNAME('POSITION',8)
        CALL YNAME('AMPLITUDE OF MATCHED FILTER',27)
        CALL HEADIN('MATCHED FILTER RESPONSE',23,2.0,1)
        CALL MESSAG('TRACKED VEH',11,.25,5.8)
        CALL MESSAG('WHEELED VEH',11,2.00,5.8)
        CALL MESSAG('SHELL BLAST',11,4.00,5.8)
        CALL MESSAG('HELO',4,6.0,5.8)
        CALL MESSAG('PERSONNEL',9,7.55,5.8)
        CALL MESSAG('SENSOR NUMBER',13,.25,.25)
        CALL INTNO(IORR,2.5,.25)
        CALL MESSAG('EVENT NUMBER',12,.25,.45)
        CALL INTNO(TESTNO,2.5,.45)
        CALL MESSAG('TIME PERIOD(SEC)',16,.25,.05)
        TS = FLOAT(IFIX(TIME(1)))
        TF = FLOAT(IFIX(TIME(1024) + 1.))
        CALL REALNO(TS,2,2.4,.05)
```

```
      CALL REALNO(TF,2,3.2,.05)
      CALL INTAXS
      CALL YAXANG (0.)
      CALL XTICKS(10)
      CALL YTICKS(10)
      CALL GRAF(0.,2000.0,10240.0,-1.0,0.2,1.0)
      CALL CURVE(UNIT,RMAT,10240,0.)
      CALL DASH
      CALL CURVE (XRAY1,YRAY,2,0)
      CALL CURVE (XRAY2,YRAY,2,0)
      CALL CURVE (XRAY3,YRAY,2,0)
      CALL CURVE (XRAY4,YRAY,2,0)
      CALL ENDPL(0)
391   RETURN
      END
C
C    SUBROUTINE MYDATA SUBTRACTS OFF THE SENSOR BIAS AND CREATES FROM THE
C    INTEGER DATA ARRAY PASSED TO IT, REAL AND COMPLEX ARRAYS.
C
      SUBROUTINE MYDATA(T,DATA,N,RA,A)
      REAL    T(N),RA(N)
      INTEGER*2 DATA(N)
      COMPLEX A(N)
      DO 10 I=1,N
         IDA=DATA(I)-2048
         IF (IDA .GT. 2047 .OR.  IDA .LT. -2048) IDA=0
         RA(I)=FLOAT(IDA)
10    CONTINUE
      SUM=0.0
      DO 20 K=1,N
         AIM=0.0
         A(K)=CMPLX(RA(K),AIM)
         SUM=SUM+RA(K)
20    CONTINUE
      AVG=SUM/FLOAT(N)
C
C   CORRECTION FOR SWITCHING SPIKES IN DATA
C
      RA(1) = 0
      RA(2) = 0
      RA(3) = 0
      RA(4) = 0
      RA(1021) = 0
      RA(1022) = 0
      RA(1023) = 0
      RA(1024) = 0
      RETURN
      END
```

```
C
C     SUBROUTINE MAXMIN FINDS THE MAXIMUM AND MINIMUM VALUES FOR THE ARRAY
C     PASSED TO IT.  IT ALSO RETURNS THE ELEMENT NUMBERS ASSOCIATED WITH
C     THE MAXIMUM AND MINIMUM VALUES.
C
      SUBROUTINE MAXMIN(A,N,K,AMAX,L,AMIN)
      REAL A(N)
      AMAX = A(1)
      AMIN = A(1)
      K=1
      L=1
      DO 10 I=2,N
         IF ((A(I)).LE.(AMAX)) GO TO 20
            AMAX=A(I)
            K=I
20    IF ((A(I)).GE.(AMIN)) GO TO 10
            AMIN=A(I)
            L=I
10    CONTINUE
      IF((ABS(AMIN)).GT.(ABS(AMAX))) AMAX = AMIN
      RETURN
      END
C
C    SUBROUTINE SPCTRM COMPUTES THE NORMALIZED POWER FOR THE COMPLEX ARRAY
C    PASSED TO IT.
C
      SUBROUTINE SPCTRM(T,RA,F,A,N,PWR,PWRDB,PHASE)
      REAL T(N),RA(N),F(N),PWR(N),PHASE(N)
      COMPLEX A(N)
      DO 10 K=1,N
         PWR(K)=CABS(A(K))**2
30    AR=REAL(A(K))
         AI=AIMAG(A(K))
         IF (AR .EQ. 0.0 .AND. AI .EQ. 0.0) GO TO 40
            PHASE(K)=ATAN2(AI,AR)
            GO TO 50
40       PHASE(K)=0.0
50    CONTINUE
10    CONTINUE
      N2=N/2
      CALL MAXMIN(PWR,N,KF,PMAX,LP,PMIN)
C    NORMALIZE POWER SPECTRUM
      DO 60 J=1,N
         PWR(J)=PWR(J)/ABS(PMAX)
60    CONTINUE
      RETURN
      END
C
```

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C                                                                        MFIOS130
C     SUBROUTINE MULTI IS THE MULTIPLE TARGET DIRECTION ROUTINE.         MFIOS140
C     DIRECTIONS ARE COMPUTED FOR UP TO FIVE TARGET CLASSES.  FOR SINGLE MFIOS150
C     TARGETS, ADAPTIVE MATCHED FILTERING IS PERFORMED ALLOWING FOR      MFIOS160
C     IMPROVED ACCURRACY.                                                MFIOS170
C                                                                        MFIOS180
      SUBROUTINE MULTI(RMAG1,RMAG2,RMAG3,RMAG4,RMAG5,RMAG6,RMAG7,        MFIOS190
     1RMAG8,RMAG9,NTYP,SCALE,IORR,THRES,ECAT,TESTNO,JL,C,TS,TF,          MFIOS200
     2V,A,ND,NW,NUMSEN,TIME,ITRGET,DIRECT,DIR,DIRC)                      MFIOS210
      INTEGER NTYP(6),C,NW,ITRGET(9,5),DIRECT,                           MFIOS220
     1NTR,ND(4),TESTNO,NUMSEN                                            MFIOS230
      REAL RMAG1(1024),RMAG2(1024),RMAG3(1024),RMAG4(1024),RMAG5(1024),  MFIOS240
     1RMAG6(1024),RMAG7(1024),RMAG8(1024),RMAG9(1024),                   MFIOS250
     2BCAT(5120),CCAT(5120),TIME(1024),DIR(5),DIRC,                      MFIOS260
     3X(9),Y(9),THETA(9),T(9),V(4),A(4),RMAG(1024)                       MFIOS270
C                                                                        MFIOS280
      NSEN = 1                                                           MFIOS290
      NH = NW/2                                                          MFIOS300
      DO 6 I1 = 1,5120                                                   MFIOS310
        CCAT(I1) = BCAT(I1)                                              MFIOS320
6     CONTINUE                                                           MFIOS330
C                                                                        MFIOS340
C     ADAPTIVE MATCHED FILTERING FOR A SINGLE TARGET IS ACCOMPLISHED     MFIOS350
C     BY USING THE SELECTED SENSOR'S SEISMIC DATA AS THE MATCHED FILTER  MFIOS360
C     WHEN COMPUTING THE IDENTIFIED TARGET'S DIRECTION.                  MFIOS370
C                                                                        MFIOS380
      NTR = 0                                                            MFIOS390
      DO 888 I14 = 1,4                                                   MFIOS400
        IF((V(I14)).NE.(0)) GO TO 5                                      MFIOS410
888   CONTINUE                                                           MFIOS420
      DO 377 JV = 1,5                                                    MFIOS430
        IF((NTYP(JV)).NE.(0)) NTR = NTR + 1                              MFIOS440
377   CONTINUE                                                           MFIOS450
      IF((NTYP(1)).EQ.(0)) GO TO 1                                       MFIOS460
      IF((NTR).NE.(1)) GO TO 1                                           MFIOS470
      NTR = NTR + 1                                                      MFIOS480
       DO 151 I2 = 1,1024                                                MFIOS490
         CCAT(I2) = RMAG1(I2)                                            MFIOS500
151    CONTINUE                                                          MFIOS510
1     IF((NTYP(2)).EQ.(0)) GO TO 2                                       MFIOS520
      IF((NTR).NE.(1)) GO TO 2                                           MFIOS530
      NTR = NTR + 1                                                      MFIOS540
       DO 102 I3 = 1,1024                                                MFIOS550
         CCAT(I3 + 1024) = RMAG2(I3)                                     MFIOS560
102    CONTINUE                                                          MFIOS570
2     IF((NTYP(3)).EQ.(0)) GO TO 3                                       MFIOS580
      IF((NTR).NE.(1)) GO TO 3                                           MFIOS590
      NTR = NTR + 1                                                      MFIOS600
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```
      DO 103 I4 = 1,1024
         CDAT(I4 + 2048) = RMAG3(I4)
103    CONTINUE
3     IF((NTYP(4)).EQ.(0)) GO TO 4
      IF((NTR).NE.(1)) GO TO 4
      NTR = NTR + 1
       DO 104 I5 = 1,1024
         CDAT(I5 + 3072) = RMAG4(I5)
104    CONTINUE
4     IF((NTYP(5)).EQ.(0)) GO TO 5
      IF((NTR).NE.(1)) GO TO 5
       DO 105 I6 = 1,1024
         CDAT(I6 + 4096) = RMAG5(I6)
105    CONTINUE
5     DO 127 J2 = 1,1024
        RMAG(J2) = 0.
127   CONTINUE
      II = 0
C
C    FOR WINDOWING OF DATA, FIND THE POSITION OF THE PEAK AMPLITUDE
C
      IF((IORR).EQ.(1)) CALL MAXMIN(RMAG1,1024,LM,RMAX,LIM,RMIN)
      IF((IORR).EQ.(2)) CALL MAXMIN(RMAG2,1024,LM,RMAX,LIM,RMIN)
      IF((IORR).EQ.(3)) CALL MAXMIN(RMAG3,1024,LM,RMAX,LIM,RMIN)
      IF((IORR).EQ.(4)) CALL MAXMIN(RMAG4,1024,LM,RMAX,LIM,RMIN)
      IF((IORR).EQ.(5)) CALL MAXMIN(RMAG5,1024,LM,RMAX,LIM,RMIN)
      IF((IORR).EQ.(6)) CALL MAXMIN(RMAG6,1024,LM,RMAX,LIM,RMIN)
      IF((IORR).EQ.(7)) CALL MAXMIN(RMAG7,1024,LM,RMAX,LIM,RMIN)
      IF((IORR).EQ.(8)) CALL MAXMIN(RMAG8,1024,LM,RMAX,LIM,RMIN)
      IF((IORR).EQ.(9)) CALL MAXMIN(RMAG9,1024,LM,RMAX,LIM,RMIN)
C
C    REPEATED CALLS TO THE MATCHED FILTER ROUTINE ARE MADE WITH WINDOWED
C    DATA FROM ALL SENSORS.
C
      DO 555 IX = 1,9
        DO 666 IY = 1,5
        ITRGET(IX,IY) = 0
666     CONTINUE
555   CONTINUE
        IF((LM - NH).LE.(0)) LM = NH
        IF((LM).GT.(1024 - NH)) LM = 1024 - NH
      DO 111 I7 = 1,NW
        RMAG(I7) = RMAG1(LM - NH + I7)
111   CONTINUE
      NTYP(1) = 0
      NTYP(2) = 0
      NTYP(3) = 0
      NTYP(4) = 0
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      NTYP(5) = 0                                                        MFI1C090
      CALL MATCH(RMAG,NTYP,SCALE,II,DIRECT,THRES,CCAT,TESTNO,JL,C,NW,    MFI1C100
     1TS,TF,TIME)                                                        MFI1C110
      ITRGET(1,1) = NTYP(1)                                              MFI1C120
      ITRGET(1,2) = NTYP(2)                                              MFI1C130
      ITRGET(1,3) = NTYP(3)                                              MFI1C140
      ITRGET(1,4) = NTYP(4)                                              MFI1C150
      ITRGET(1,5) = NTYP(5)                                              MFI1C160
      DO 112 I8 = 1,NW                                                   MFI1C170
         RMAG(I8) = RMAG2(LM - NH + I8)                                  MFI1C180
112   CONTINUE                                                           MFI1C190
      NTYP(1) = 0                                                        MFI1C200
      NTYP(2) = 0                                                        MFI1C210
      NTYP(3) = 0                                                        MFI1C220
      NTYP(4) = 0                                                        MFI1C230
      NTYP(5) = 0                                                        MFI1C240
      CALL MATCH(RMAG,NTYP,SCALE,II,DIRECT,THRES,CCAT,TESTNO,JL,C,NW,    MFI1C250
     1TS,TF,TIME)                                                        MFI1C260
      ITRGET(2,1) = NTYP(1)                                              MFI1C270
      ITRGET(2,2) = NTYP(2)                                              MFI1C280
      ITRGET(2,3) = NTYP(3)                                              MFI1C290
      ITRGET(2,4) = NTYP(4)                                              MFI1C300
      ITRGET(2,5) = NTYP(5)                                              MFI1C310
      DO 113 I9 = 1,NW                                                   MFI1C320
         RMAG(I9) = RMAG3(LM - NH + I9)                                  MFI1C330
113   CONTINUE                                                           MFI1C340
      NTYP(1) = 0                                                        MFI1C350
      NTYP(2) = 0                                                        MFI1C360
      NTYP(3) = 0                                                        MFI1C370
      NTYP(4) = 0                                                        MFI1C380
      NTYP(5) = 0                                                        MFI1C390
      CALL MATCH(RMAG,NTYP,SCALE,II,DIRECT,THRES,CCAT,TESTNO,JL,C,NW,    MFI1C400
     1TS,TF,TIME)                                                        MFI1C410
      ITRGET(3,1) = NTYP(1)                                              MFI1C420
      ITRGET(3,2) = NTYP(2)                                              MFI1C430
      ITRGET(3,3) = NTYP(3)                                              MFI1C440
      ITRGET(3,4) = NTYP(4)                                              MFI1C450
      ITRGET(3,5) = NTYP(5)                                              MFI1C460
      DO 114 IA = 1,NW                                                   MFI1C470
         RMAG(IA) = RMAG4(LM - NH + IA)                                  MFI1C480
114   CONTINUE                                                           MFI1C490
      NTYP(1) = 0                                                        MFI1C500
      NTYP(2) = 0                                                        MFI1C510
      NTYP(3) = 0                                                        MFI1C520
      NTYP(4) = 0                                                        MFI1C530
      NTYP(5) = 0                                                        MFI1C540
      CALL MATCH(RMAG,NTYP,SCALE,II,DIRECT,THRES,CCAT,TESTNO,JL,C,NW,    MFI1C550
     1TS,TF,TIME)                                                        MFI1C560
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      ITRGET(4,1) = NTYP(1)                                            MFI1C570
      ITRGET(4,2) = NTYP(2)                                            MFI1C580
      ITRGET(4,3) = NTYP(3)                                            MFI1C590
      ITRGET(4,4) = NTYP(4)                                            MFI1C600
      ITRGET(4,5) = NTYP(5)                                            MFI1C610
      DO 115 IB = 1,NW                                                 MFI1C620
        RMAG(IB) = RMAG5(LM - NH + IB)                                 MFI1C630
  115 CONTINUE                                                         MFI1C640
      NTYP(1) = 0                                                      MFI1C650
      NTYP(2) = 0                                                      MFI1C660
      NTYP(3) = 0                                                      MFI1C670
      NTYP(4) = 0                                                      MFI1C680
      NTYP(5) = 0                                                      MFI1C690
      CALL MATCH(RMAG,NTYP,SCALE,II,DIRECT,THRES,CCAT,TESTNO,JL,C,NW,  MFI1C700
     1TS,TF,TIME)                                                      MFI1C710
      ITRGET(5,1) = NTYP(1)                                            MFI1C720
      ITRGET(5,2) = NTYP(2)                                            MFI1C730
      ITRGET(5,3) = NTYP(3)                                            MFI1C740
      ITRGET(5,4) = NTYP(4)                                            MFI1C750
      ITRGET(5,5) = NTYP(5)                                            MFI1C760
      DO 116 IC = 1,NW                                                 MFI1C770
        RMAG(IC) = RMAG6(LM - NH + IC)                                 MFI1C780
  116 CONTINUE                                                         MFI1C790
      NTYP(1) = 0                                                      MFI1C800
      NTYP(2) = 0                                                      MFI1C810
      NTYP(3) = 0                                                      MFI1C820
      NTYP(4) = 0                                                      MFI1C830
      NTYP(5) = 0                                                      MFI1C840
      CALL MATCH(RMAG,NTYP,SCALE,II,DIRECT,THRES,CCAT,TESTNO,JL,C,NW,  MFI1C850
     1TS,TF,TIME)                                                      MFI1C860
      ITRGET(6,1) = NTYP(1)                                            MFI1C870
      ITRGET(6,2) = NTYP(2)                                            MFI1C880
      ITRGET(6,3) = NTYP(3)                                            MFI1C890
      ITRGET(6,4) = NTYP(4)                                            MFI1C900
      ITRGET(6,5) = NTYP(5)                                            MFI1C910
      IF((NUMSEN).EQ.(6)) GO TO 101                                    MFI1C920
      DO 117 IC = 1,NW                                                 MFI1C930
        RMAG(IC) = RMAG7(LM - NH + IC)                                 MFI1C940
  117 CONTINUE                                                         MFI1C950
      NTYP(1) = 0                                                      MFI1C960
      NTYP(2) = 0                                                      MFI1C970
      NTYP(3) = 0                                                      MFI1C980
      NTYP(4) = 0                                                      MFI1C990
      NTYP(5) = 0                                                      MFI11C00
      CALL MATCH(RMAG,NTYP,SCALE,II,DIRECT,THRES,CCAT,TESTNO,JL,C,NW,  MFI11C10
     1TS,TF,TIME)                                                      MFI11C20
      ITRGET(7,1) = NTYP(1)                                            MFI11C30
      ITRGET(7,2) = NTYP(2)                                            MFI11C40
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      ITRGET(7,3) = NTYP(3)                                            MFI11050
      ITRGET(7,4) = NTYP(4)                                            MFI11060
      ITRGET(7,5) = NTYP(5)                                            MFI11070
      DO 118 IE = 1,NW                                                 MFI11080
        RMAG(IE) = RMAG8(LM - NH + IE)                                 MFI11090
118   CONTINUE                                                         MFI11100
      NTYP(1) = 0                                                      MFI11110
      NTYP(2) = 0                                                      MFI11120
      NTYP(3) = 0                                                      MFI11130
      NTYP(4) = 0                                                      MFI11140
      NTYP(5) = 0                                                      MFI11150
      CALL MATCH(RMAG,NTYP,SCALE,II,DIRECT,THRES,CCAT,TESTNO,JL,C,NW,  MFI11160
     1TS,TF,TIME)                                                      MFI11170
      ITRGET(8,1) = NTYP(1)                                            MFI11180
      ITRGET(8,2) = NTYP(2)                                            MFI11190
      ITRGET(8,3) = NTYP(3)                                            MFI11200
      ITRGET(8,4) = NTYP(4)                                            MFI11210
      ITRGET(8,5) = NTYP(5)                                            MFI11220
      DO 119 IF = 1,NW                                                 MFI11230
        RMAG(IF) = RMAG9(LM - NH + IF)                                 MFI11240
119   CONTINUE                                                         MFI11250
      NTYP(1) = 0                                                      MFI11260
      NTYP(2) = 0                                                      MFI11270
      NTYP(3) = 0                                                      MFI11280
      NTYP(4) = 0                                                      MFI11290
      NTYP(5) = 0                                                      MFI11300
      CALL MATCH(RMAG,NTYP,SCALE,II,DIRECT,THRES,CCAT,TESTNO,JL,C,NW,  MFI11310
     1TS,TF,TIME)                                                      MFI11320
      ITRGET(9,1) = NTYP(1)                                            MFI11330
      ITRGET(9,2) = NTYP(2)                                            MFI11340
      ITRGET(9,3) = NTYP(3)                                            MFI11350
      ITRGET(9,4) = NTYP(4)                                            MFI11360
      ITRGET(9,5) = NTYP(5)                                            MFI11370
      NTYP(1) = 0                                                      MFI11380
      NTYP(2) = 0                                                      MFI11390
      NTYP(3) = 0                                                      MFI11400
      NTYP(4) = 0                                                      MFI11410
      NTYP(5) = 0                                                      MFI11420
       DO 679 IN = 1,5                                                 MFI11430
         DIR(IN) = 999.                                                MFI11440
679    CONTINUE                                                        MFI11450
101    RETURN                                                          MFI11460
       END                                                             MFI11470
C                                                                      MFI11480
C    MULTIPLE DIRECTION OUTPUT PLOTTING                                MFI11490
C                                                                      MFI11500
      SUBROUTINE MLTPLT(C,SCALE,TESTNO,TS,TF,DIR,V,A,ND,ITRGET)        MFI11510
      INTEGER C,ND(4),ITRGET(9,5)                                      MFI11520
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      REAL DIR(5),V(4),A(4)                                             MFI11530
      IF((C).EQ.(1)) CALL COMPRS                                        MFI11540
      IF((C).NE.(1)) CALL TEK618                                        MFI11550
      CALL PAGE(11.0,8.5)                                               MFI11560
      CALL NOBRDR                                                       MFI11570
      CALL BLOWUP(SCALE)                                                MFI11580
      CALL AREA2D(10.0,6.0)                                             MFI11590
      CALL FRAME                                                        MFI11600
      CALL HEADIN('MULTIPLE TARGET - MATCHED FILTER OUTPUT',39,2.0,1)   MFI11610
      CALL MESSAG('EVENT NUMBER ',13,3.0,5.8)                           MFI11620
      CALL INTNO(TESTNO,5.0,5.8)                                        MFI11630
      CALL MESSAG('TIME PERIOD(SEC)',16,3.0,5.4)                        MFI11640
      CALL REALNO(TS,2,4.9,5.4)                                         MFI11650
      CALL REALNO(TF,2,5.7,5.4)                                         MFI11660
      IF(((ITRGET(1,1)).NE.(0)).AND.((DIR(1)).NE.(999.)))              MFI11670
     1 CALL MESSAG('TRACKED VEHICLE    DIRECTION =',29,3.0,5.0)         MFI11680
      IF(((ITRGET(1,1)).NE.(0)).AND.((DIR(1)).NE.(999.)))               MFI11690
     1 CALL REALNO(DIR(1),2,6.5,5.0)                                    MFI11700
      IF(((ITRGET(1,2)).NE.(0)).AND.((DIR(2)).NE.(999.)))               MFI11710
     1 CALL MESSAG('WHEELED VEHICLE    DIRECTION =',29,3.0,4.6)         MFI11720
      IF(((ITRGET(1,2)).NE.(0)).AND.((DIR(2)).NE.(999.)))               MFI11730
     1 CALL REALNO(DIR(2),2,6.5,4.6)                                    MFI11740
      IF(((ITRGET(1,3)).NE.(0)).AND.((DIR(3)).NE.(999.)))               MFI11750
     1 CALL MESSAG('SHELL BLAST        DIRECTION =',29,3.0,4.2)         MFI11760
      IF(((ITRGET(1,3)).NE.(0)).AND.((DIR(3)).NE.(999.)))               MFI11770
     1 CALL REALNO(DIR(3),2,6.5,4.2)                                    MFI11780
      IF(((ITRGET(1,4)).NE.(0)).AND.((DIR(4)).NE.(999.)))               MFI11790
     1 CALL MESSAG('HELICOPTER         DIRECTION =',29,3.0,3.8)         MFI11800
      IF(((ITRGET(1,4)).NE.(0)).AND.((DIR(4)).NE.(999.)))               MFI11810
     1 CALL REALNO(DIR(4),2,6.5,3.8)                                    MFI11820
      IF(((ITRGET(1,5)).NE.(0)).AND.((DIR(5)).NE.(999.)))               MFI11830
     1 CALL MESSAG('PERSONNEL          DIRECTION =',29,3.0,3.4)         MFI11840
      IF(((ITRGET(1,5)).NE.(0)).AND.((DIR(5)).NE.(999.)))               MFI11850
     1 CALL REALNO(DIR(5),2,6.5,3.4)                                    MFI11860
      CALL MESSAG('SIMULATED TRKD VEHICLE TARGET FREQUENCY',39,3.0,2.8) MFI11870
      CALL REALNO(V(1),2,8.0,2.8)                                       MFI11880
      CALL MESSAG('AMPLITUDE',9,4.0,2.6)                                MFI11890
      CALL MESSAG('DIRECTION',9,4.0,2.4)                                MFI11900
      CALL REALNO(A(1),4,5.5,2.6)                                       MFI11910
      D = FLOAT(NO(1))                                                  MFI11920
      CALL REALNO(D,4,5.5,2.4)                                          MFI11930
      CALL MESSAG('SIMULATED WHLD VEHICLE TARGET FREQUENCY',39,3.0,2.2) MFI11940
      CALL REALNO(V(2),2,8.0,2.2)                                       MFI11950
      CALL MESSAG('AMPLITUDE',9,4.0,2.0)                                MFI11960
      CALL MESSAG('DIRECTION',9,4.0,1.80)                               MFI11970
      CALL REALNO(A(2),4,5.5,2.0)                                       MFI11980
      D = FLOAT(NO(2))                                                  MFI11990
      CALL REALNO(D,4,5.5,1.8)                                          MFI12000
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      CALL MESSAG('SIMULATED HELICOPTER TARGET FREQUENCY',37,3.0,1.6)    MFI12010
      CALL REALNO(V(3),2,8.0,1.6)                                        MFI12020
      CALL MESSAG('AMPLITUDE',9,4.0,1.4)                                 MFI12030
      CALL MESSAG('DIRECTION',9,4.0,1.2)                                 MFI12040
      CALL REALNO(A(3),4,5.5,1.4)                                        MFI12050
      D = FLOAT(NC(3))                                                   MFI12060
      CALL REALNO(D,4,5.5,1.2)                                           MFI12070
      CALL MESSAG('SIMULATED PERSONNEL TARGET FREQUENCY',36,3.0,1.0)     MFI12080
      CALL REALNO(V(4),2,8.0,1.0)                                        MFI12090
      CALL MESSAG('AMPLITUDE',9,4.0,0.8)                                 MFI12100
      CALL MESSAG('DIRECTION',9,4.0,0.6)                                 MFI12110
      CALL REALNO(A(4),4,5.5,0.8)                                        MFI12120
      D = FLOAT(NC(4))                                                   MFI12130
      CALL REALNO(D,4,5.5,0.6)                                           MFI12140
      CALL ENDPL(0)                                                      MFI12150
      RETURN                                                             MFI12160
      END                                                                MFI12170
C                                                                        MFI12180
C     SUBROUTINE RMS COMPUTES THE ROOT MEAN SQUARE VALUE OF THE N-ARRAY  MFI12190
C     DATA PASSED TO IT                                                  MFI12200
C                                                                        MFI12210
      SUBROUTINE RMS(A,N,TMAX)                                           MFI12220
      REAL A(N)                                                          MFI12230
      TMAX = 0.                                                          MFI12240
      DO 200 I = 1,N                                                     MFI12250
        TMAX = (A(I))**2 + TMAX                                          MFI12260
200   CONTINUE                                                           MFI12270
      TMAX =  SQRT(TMAX)                                                 MFI12280
      RETURN                                                             MFI12290
      END                                                                MFI12300
C                                                                        MFI12310
C     SUBROUTINE AVG COMPUTES THE AVERAGE VALUE OF THE N-ARRAY DATA PASSEDMFI12320
C     TO IT                                                              MFI12330
C                                                                        MFI12340
      SUBROUTINE AVG(A,N,AAVG)                                           MFI12350
      REAL A(N)                                                          MFI12360
      AAVG = 0.                                                          MFI12370
      DO 100 I = 1,N                                                     MFI12380
        AAVG = A(N) + AAVG                                               MFI12390
100   CONTINUE                                                           MFI12400
      AAVG = AAVG/FLOAT(N)                                               MFI12410
      RETURN                                                             MFI12420
      END                                                                MFI12430
C                                                                        MFI12440
C     SUBROUTINE SIMULATE ALLOWS FOR THE MODIFICATION OF EXPERIMENTAL    MFI12450
C     DATA TO INCLUDE UP TO FOUR SIMULATED TARGETS, AND MODIFICATION OF  MFI12460
C     SEISMIC SIGNAL AMPLITUDES ABOVE THE SELECTED NOISE LEVEL.          MFI12470
C                                                                        MFI12480
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      SUBROUTINE SIMULT(RA1,RA2,RA3,RA4,RA5,RA6,RA7,RA8,RA9,            MFI12490
     1A1,A2,A3,A4,A5,A6,A7,A8,A9,                                       MFI12500
     2V,A,ND,INOISE,TIME,JL,P,REDUCE,NUMSEN)                            MFI12510
      INTEGER ND(4),NUMSEN                                              MFI12520
      REAL RA1(1024),RA2(1024),RA3(1024),RA4(1024),RA5(1024),RA6(1024), MFI12530
     1RA7(1024),RA8(1024),RA9(1024),                                    MFI12540
     2V(4),A(4),INOISE,TIME(1024),P(9,4),REDUCE                         MFI12550
      COMPLEX A1(1024),A2(1024),A3(1024),A4(1024),A5(1024),             MFI12560
     1A6(1024),A7(1024),A8(1024),A9(1024)                               MFI12570
      WRITE(6,10)                                                       MFI12580
   10 FORMAT('0','ENTER THE FOUR SIMULATION FREQUENCIES-REAL-')         MFI12590
      WRITE(6,11)                                                       MFI12600
   11 FORMAT('0','ENTER FREQUENCY')                                     MFI12610
      READ(10,12)V(1)                                                   MFI12620
      WRITE(6,11)                                                       MFI12630
      READ(10,12)V(2)                                                   MFI12640
      WRITE(6,11)                                                       MFI12650
      READ(10,12)V(3)                                                   MFI12660
      WRITE(6,11)                                                       MFI12670
      READ(10,12)V(4)                                                   MFI12680
   12 FORMAT(F2.0)                                                      MFI12690
      WRITE(6,13)                                                       MFI12700
   13 FORMAT('0','ENTER AMPLITUDES FOR EACH FREQUENCY-REAL-')           MFI12710
      WRITE(6,14)                                                       MFI12720
   14 FORMAT('0','ENTER AMPLITUDE')                                     MFI12730
      READ(10,15)A(1)                                                   MFI12740
      WRITE(6,14)                                                       MFI12750
      READ(10,15)A(2)                                                   MFI12760
      WRITE(6,14)                                                       MFI12770
      READ(10,15)A(3)                                                   MFI12780
      WRITE(6,14)                                                       MFI12790
      READ(10,15)A(4)                                                   MFI12800
   15 FORMAT(F5.1)                                                      MFI12810
      WRITE(6,16)                                                       MFI12820
      WRITE(6,18)                                                       MFI12830
      WRITE(6,19)                                                       MFI12840
   16 FORMAT('0','ENTER TARGET ANGLE FOR EACH FREQUENCY-I3-')           MFI12850
   18 FORMAT('0','SIX SENSORS ALLOWABLE ANGLES;0,60,120,180,240,300')   MFI12860
   19 FORMAT('0','FOR NINE SENSORS;0,40,80,120,160,200,240,280,320')    MFI12870
      WRITE(6,17)                                                       MFI12880
   17 FORMAT('0','ENTER ANGLE')                                         MFI12890
      READ(10,55)ND(1)                                                  MFI12900
      WRITE(6,17)                                                       MFI12910
      READ(10,55)ND(2)                                                  MFI12920
      WRITE(6,17)                                                       MFI12930
      READ(10,55)ND(3)                                                  MFI12940
      WRITE(6,17)                                                       MFI12950
      READ(10,55)ND(4)                                                  MFI12960
```

```
55    FORMAT(I3)
      WRITE(6,21)
      RECUCE = 1.
21    FORMAT('0','TO MODIFY AMPLITUDE CF SIGNAL ABCVE NOISE THRESHOLD')
      WRITE(6,22)
22    FORMAT('0','ENTER - 1 -,ELSE ENTER - 2 -')
      READ(10,23)N
23    FORMAT(I1)
      IF((N).NE.(1)) GC TC 26
      WRITE(6,24)
24    FORMAT('0','ENTER NOISE REDUCTION FACTOR, 1 OR GREATER-REAL-')
      READ(10,25)REDUCE
25    FORMAT(F6.1)
26    PI = 3.141593
      PP = 2*PI/360.0
C
C    PHASE DIFFERENCES ARE USED FOR CREATING THE SIMULATED TARGET'S
C    ARRIVAL ANGLE
C
      DO 1 I = 1,4
      IF((NUMSEN).EQ.(9)) GO TO 42
        IF((NC(I)).NE.(0)) GO TO 61
         P(1,I) = C.
         P(2,I) = -45.
         P(3,I) = -135.
         P(4,I) = -180.
         P(5,I) = -135.
         P(6,I) = -45.
61       IF((NC(I)).NE.(60)) GO TO 62
         P(1,I) = -45.
         P(2,I) =  0.
         P(3,I) = -45.
         P(4,I) = -135.
         P(5,I) = -180.
         P(6,I) = -135.
62       IF((NC(I)).NE.(120)) GO TO 63
         P(1,I) = -135.
         P(2,I) = -45.
         P(3,I) =  0.
         P(4,I) = -45.
         P(5,I) = -135.
         P(6,I) = -180.
63       IF((NC(I)).NE.(180)) GO TO 64
         P(1,I) = -180.
         P(2,I) = -135.
         P(3,I) = -45.
         P(4,I) =  0.
         P(5,I) = -45.
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      P(6,I) = -135.                                                    MFI13450
 64   IF((NC(I)).NE.(240)) GO TO 65                                     MFI13460
      P(1,I) = -135.                                                    MFI13470
      P(2,I) = -180.                                                    MFI13480
      P(3,I) = -135.                                                    MFI13490
      P(4,I) = -45.                                                     MFI13500
      P(5,I) =  0.                                                      MFI13510
      P(6,I) = -45.                                                     MFI13520
 65   IF((NC(I)).NE.(300)) GO TO 42                                     MFI13530
      P(1,I) = -45.                                                     MFI13540
      P(2,I) = -135.                                                    MFI13550
      P(3,I) = -180.                                                    MFI13560
      P(4,I) = -135.                                                    MFI13570
      P(5,I) = -45.                                                     MFI13580
      P(6,I) =  0.                                                      MFI13590
 42   IF ((NUMSEN).NE.(9)) GO TO 41                                     MFI13600
      IF((NC(I)).NE.(0)) GO TO 91                                       MFI13610
      P(1,I) =  0.                                                      MFI13620
      P(2,I) = -21.3                                                    MFI13630
      P(3,I) = -76.                                                     MFI13640
      P(4,I) = -138.7                                                   MFI13650
      P(5,I) = -180.                                                    MFI13660
      P(6,I) = -180.                                                    MFI13670
      P(7,I) = -138.7                                                   MFI13680
      P(8,I) = -76.                                                     MFI13690
      P(9,I) = -21.3                                                    MFI13700
 91   IF((NC(I)).NE.(40)) GO TO 92                                      MFI13710
      P(1,I) = -21.3                                                    MFI13720
      P(2,I) =  0.                                                      MFI13730
      P(3,I) = -21.3                                                    MFI13740
      P(4,I) = -76.                                                     MFI13750
      P(5,I) = -138.7                                                   MFI13760
      P(6,I) = -180.                                                    MFI13770
      P(7,I) = -180.                                                    MFI13780
      P(8,I) = -138.7                                                   MFI13790
      P(9,I) = -76.                                                     MFI13800
 92   IF((NC(I)).NE.(80)) GO TO 93                                      MFI13810
      P(1,I) = -76.                                                     MFI13820
      P(2,I) = -21.3                                                    MFI13830
      P(3,I) =  0.                                                      MFI13840
      P(4,I) = -21.3                                                    MFI13850
      P(5,I) = -76.                                                     MFI13860
      P(6,I) = -138.7                                                   MFI13870
      P(7,I) = -180.                                                    MFI13880
      P(8,I) = -180.                                                    MFI13890
      P(9,I) = -138.7                                                   MFI13900
 93   IF((NC(I)).NE.(120)) GO TO 94                                     MFI13910
      P(1,I) = -138.7                                                   MFI13920
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      P(2,I) = -76.                                                     MFI113930
      P(3,I) = -21.3                                                    MFI113940
      P(4,I) =  0.                                                      MFI113950
      P(5,I) = -21.3                                                    MFI113960
      P(6,I) = -76.                                                     MFI113970
      P(7,I) = -138.7                                                   MFI113980
      P(8,I) = -180.                                                    MFI113990
      P(9,I) = -180.                                                    MFI114000
   94 IF((NC(I)).NE.(160)) GO TO 95                                     MFI114010
      P(1,I) = -180.                                                    MFI114020
      P(2,I) = -138.7                                                   MFI114030
      P(3,I) = -76.                                                     MFI114040
      P(4,I) = -21.3                                                    MFI114050
      P(5,I) =  0.                                                      MFI114060
      P(6,I) = -21.3                                                    MFI114070
      P(7,I) = -76.                                                     MFI114080
      P(8,I) = -138.7                                                   MFI114090
      P(9,I) = -180.                                                    MFI114100
   95 IF((NC(I)).NE.(200)) GO TO 96                                     MFI114110
      P(1,I) = -180.                                                    MFI114120
      P(2,I) = -180.                                                    MFI114130
      P(3,I) = -138.7                                                   MFI114140
      P(4,I) = -76.                                                     MFI114150
      P(5,I) = -21.3                                                    MFI114160
      P(6,I) =  0.                                                      MFI114170
      P(7,I) = -21.3                                                    MFI114180
      P(8,I) = -76.                                                     MFI114190
      P(9,I) = -138.7                                                   MFI114200
   96 IF((NC(I)).NE.(240)) GO TO 97                                     MFI114210
      P(1,I) = -138.7                                                   MFI114220
      P(2,I) = -180.                                                    MFI114230
      P(3,I) = -180.                                                    MFI114240
      P(4,I) = -138.7                                                   MFI114250
      P(5,I) = -76.                                                     MFI114260
      P(6,I) = -21.3                                                    MFI114270
      P(7,I) =  0.                                                      MFI114280
      P(8,I) = -21.3                                                    MFI114290
      P(9,I) = -76.                                                     MFI114300
   97 IF((NC(I)).NE.(280)) GO TO 98                                     MFI114310
      P(1,I) = -76.                                                     MFI114320
      P(2,I) = -138.7                                                   MFI114330
      P(3,I) = -180.                                                    MFI114340
      P(4,I) = -180.                                                    MFI114350
      P(5,I) = -138.7                                                   MFI114360
      P(6,I) = -76.                                                     MFI114370
      P(7,I) = -21.3                                                    MFI114380
      P(8,I) =  0.                                                      MFI114390
      P(9,I) = -21.3                                                    MFI114400
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98      IF((NC(I)).NE.(320)) GO TO 41
        P(1,I) = -21.3
        P(2,I) = -76.
        P(3,I) = -138.7
        P(4,I) = -180.
        P(5,I) = -180.
        P(6,I) = -138.7
        P(7,I) = -76.
        P(8,I) = -21.3
        P(9,I) =  0.
C
C     ADDITION OF THE SIMULATED SIGNALS TO EACH SENSORS DATA
C
41      DO 2 J = 1,1024
        RA1(J) = RA1(J) + (A(I)*COS(2*PI*V(I)*TIME(J) + PP*P(1,I)))
        RA2(J) = RA2(J) + (A(I)*COS(2*PI*V(I)*TIME(J) + PP*P(2,I)))
        RA3(J) = RA3(J) + (A(I)*COS(2*PI*V(I)*TIME(J) + PP*P(3,I)))
        RA4(J) = RA4(J) + (A(I)*COS(2*PI*V(I)*TIME(J) + PP*P(4,I)))
        RA5(J) = RA5(J) + (A(I)*COS(2*PI*V(I)*TIME(J) + PP*P(5,I)))
        RA6(J) = RA6(J) + (A(I)*COS(2*PI*V(I)*TIME(J) + PP*P(6,I)))
        IF((NUMSEN).EQ.(6)) GO TO 2
        RA7(J) = RA7(J) + (A(I)*COS(2*PI*V(I)*TIME(J) + PP*P(7,I)))
        RA8(J) = RA8(J) + (A(I)*COS(2*PI*V(I)*TIME(J) + PP*P(8,I)))
        RA9(J) = RA9(J) + (A(I)*COS(2*PI*V(I)*TIME(J) + PP*P(9,I)))
2     CONTINUE
1     CONTINUE
C
C     SUPRESSION OR ENHANCEMENT OF SEISMIC SIGNALS ABOVE THE NOISE LEVEL
C
      DO 3 K = 1,1024
        IF((ABS(RA1(K))).GT.(TNOISE)) RA1(K) = RA1(K)/REDUCE
        IF((ABS(RA2(K))).GT.(TNOISE)) RA2(K) = RA2(K)/REDUCE
        IF((ABS(RA3(K))).GT.(TNOISE)) RA3(K) = RA3(K)/REDUCE
        IF((ABS(RA4(K))).GT.(TNOISE)) RA4(K) = RA4(K)/REDUCE
        IF((ABS(RA5(K))).GT.(TNOISE)) RA5(K) = RA5(K)/REDUCE
        IF((ABS(RA6(K))).GT.(TNOISE)) RA6(K) = RA6(K)/REDUCE
        IF((NUMSEN).EQ.(6)) GO TO 3
        IF((ABS(RA7(K))).GT.(TNOISE)) RA7(K) = RA7(K)/REDUCE
        IF((ABS(RA8(K))).GT.(TNOISE)) RA8(K) = RA8(K)/REDUCE
        IF((ABS(RA9(K))).GT.(TNOISE)) RA9(K) = RA9(K)/REDUCE
3     CONTINUE
      DO 20 K1 = 1,1024
        ABC = 0.
        A1(K1) = CMPLX(RA1(K1),ABC)
        A2(K1) = CMPLX(RA2(K1),ABC)
        A3(K1) = CMPLX(RA3(K1),ABC)
        A4(K1) = CMPLX(RA4(K1),ABC)
        A5(K1) = CMPLX(RA5(K1),ABC)
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```
      A6(K1) = CMPLX(RA6(K1),ABC)
      IF((NUMSEN).EQ.(6)) GO TO 20
      A7(K1) = CMPLX(RA7(K1),ABC)
      A8(K1) = CMPLX(RA8(K1),ABC)
      A9(K1) = CMPLX(RA9(K1),ABC)
20    CONTINUE
30    RETURN
      END
C
C     LEAST MEAN SQUARES POLYNOMIAL CURVE FITTING ALGORITHM
C
      SUBROUTINE LMS (NTAR,DIRC,NUMSEN,C,SCALE,TESTNC,TIME,NFRM,Y,
     1VX,X,TT,INDEX,NCR,TRIX,B,WKAREA)
      DIMENSION TRIX(9,9),B(9),WKAREA(108)
      INTEGER NTAR(9),T(9),C,NHALF,MIN,NUMSEN,TESTNC,NFRM
      REAL P,FMIN,S,XS(16),X(9),A(9),Y(360),
     1VX(360),TT(9),TIME(1024),DIRC,SCALE,C
C
C     FIND FIRST SENSOR TO MATCH THE INPUT SIGNAL
C
        MIN = NTAR(1)
        MARK = 1
        IF((NTAR(1)).LT.(1)) GO TO 66
        DO 97 I17 =1,9
          T(I17) = 0
          TT(I17) = 0.
          WRITE(6,53) NTAR(I17)
97    CONTINUE
53    FORMAT(I7)
        DO 11 I2 = 2,NUMSEN
          IF((NTAR(I2)).GE.(MIN)) GO TO 11
          MIN = NTAR(I2)
          MARK = I2
11      CONTINUE
      DO 46 IE = 1,360
        Y(IE) = 0.
        VX(IE) = 0.
46    CONTINUE
C
C     CENTER THE PARABOLA
C
      IF((MIN).EQ.(0)) GO TO 66
      DO 21 K1 = 1,NUMSEN
        INA = 1
        IF((NUMSEN).EQ.(6)) INA = 0
        N = NUMSEN/2 - MARK + K1 + INA
        IF((N).GT.(NUMSEN)) N = N - NUMSEN
        IF((N).LT.(1)) N = N + NUMSEN
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      T(N) = NTAR(K1)                                                   MFI15370
21    CONTINUE                                                          MFI15380
      DO 41 L = 1,NUMSEN                                                MFI15390
         T(L) = T(L) - MIN                                              MFI15400
         TT(L) = FLOAT(T(L))                                            MFI15410
41    CONTINUE                                                          MFI15420
      DO 10 I3 = 1,16                                                   MFI15430
         XS(I3) = 0.                                                    MFI15440
10    CONTINUE                                                          MFI15450
      X(1) = 0.                                                         MFI15460
      LN = NUMSEN - 1                                                   MFI15470
      DO 130 I4 = 1,LN                                                  MFI15480
         IF((NUMSEN).EQ.(6)) X(I4 + 1) = (FLOAT(I4*60))/360.            MFI15490
         IF((NUMSEN).EQ.(9)) X(I4 + 1) = (FLOAT(I4*40))/320.            MFI15500
130   CONTINUE                                                          MFI15510
C                                                                       MFI15520
C    LOAD THE MATRICES FOR THE LEAST MEAN SQUARES POLYNOMIAL SOLUTION   MFI15530
C                                                                       MFI15540
      IF(NUMSEN.EQ.6) X(7) =0                                           MFI15550
      IF(NUMSEN.EQ.6) X(8) =0                                           MFI15560
      IF(NUMSEN.EQ.6) X(9) =0                                           MFI15570
      NTC = 2*NUMSEN - 2                                                MFI15580
      DO 20 N1 = 1,NTC                                                  MFI15590
         DO 30 K3 = 1,NUMSEN                                            MFI15600
            XS(N1) = X(K3)**N1 + XS(N1)                                 MFI15610
30    CONTINUE                                                          MFI15620
20    CONTINUE                                                          MFI15630
      DO 47 I2A = 1,9                                                   MFI15640
         DO 49 I3A = 1,9                                                MFI15650
          TRIX(I2A,I3A) = 0.                                            MFI15660
49       CONTINUE                                                       MFI15670
47    CONTINUE                                                          MFI15680
      TRIX(1,1) = NUMSEN                                                MFI15690
      DO 50 N2 = 2,NUMSEN                                               MFI15700
       TRIX(1,N2) = XS(N2 - 1)                                          MFI15710
50    CONTINUE                                                          MFI15720
      DO 40 I5 = 1,NUMSEN                                               MFI15730
        TRIX(2,I5) = XS(I5)                                             MFI15740
        TRIX(3,I5) = XS(I5 + 1)                                         MFI15750
        TRIX(4,I5) = XS(I5 + 2)                                         MFI15760
        TRIX(5,I5) = XS(I5 + 3)                                         MFI15770
        TRIX(6,I5) = XS(I5 + 4)                                         MFI15780
        IF((NUMSEN).EQ.(6)) GO TO 40                                    MFI15790
        TRIX(7,I5) = XS(I5 + 5)                                         MFI15800
        TRIX(8,I5) = XS(I5 + 6)                                         MFI15810
        TRIX(9,I5) = XS(I5 + 7)                                         MFI15820
40    CONTINUE                                                          MFI15830
      DO 60 I6 = 1,9                                                    MFI15840
```

```
         B(I6) = 0
60    CONTINUE
      DO 70 I7 = 2,NUMSEN
         DO 80 K4 = 1,NUMSEN
            B(I7) = B(I7) + (X(K4)**(I7 - 1))*(FLOAT(T(K4)))
80       CONTINUE
70    CONTINUE
      DO 90 I8 = 1,NUMSEN
         B(1) = B(1) +(FLOAT(T(I8)))
90    CONTINUE
      WRITE(6,1)
      WRITE(6,2)
1     FORMAT('0','ENTER DEGREE OF POLYNOMIAL DESIRED -I1-')
2     FORMAT('0','FOR SIX SENSORS ENTER 2 - 4, FOR NINE ENTER 2 - 7')
      READ(10,3) NOR
3     FORMAT(I1)
      NZ = NOR + 1
C
C   CALL THE MATRIX SOLVER LEQT2F VIA SUBROUTINE SOLV TO FIND THE
C   COEFFICIENTS FOR THE LEAST MEAN SQUARES POLYNOMIAL
C
      CALL SOLV (TRIX,NZ,B)
         PMIN = 1E20
         MINI = 1
         DIVIDE = 40.
         IF((NUMSEN).EQ.(6)) DIVIDE = 60.
      NO = NOR + 2
       DO 110 I9 = NO,9
        B(I9) = 0
110   CONTINUE
      IF((NUMSEN).EQ.(6)) INDEX = 360
      IF((NUMSEN).EQ.(9)) INDEX = 320
C
C   CALCULATE PLOTTING DATA FROM THE LEAST MEAN SQUARES POLYNOMIAL
C
      DO 120 NR = 1,INDEX
      Q = FLOAT(NR)/FLOAT(INDEX)
         P = B(1) + B(2)*(Q) + B(3)*(Q**2)
     1 + B(4)*(Q**3)
     2 + B(5)*(Q**4)
     3 + B(6)*(Q**5)
     4 + B(7)*(Q**6)
     5 + B(8)*(Q**7)
     6 + B(9)*(Q**8)
       VX(NR) = FLOAT(NR) + FLOAT(MARK - NUMSEN/2 - INA)*DIVIDE -1.
       Y(NR) = P
      IF((P).GT.(PMIN)) GO TO 120
      MINI = NR
```

```
      FMIN = F
120   CONTINUE
      NHALF = NUMSEN/2
      DIRC = MINI + (MARK - NUMSEN/2 - INA)*DIVIDE
      DO 77 IB = 1,NUMSEN
       X(IB) = X(IB)*FLOAT(INDEX) + FLOAT(MARK - NUMSEN/2 -INA)*DIVIDE
77    CONTINUE
66    RETURN
      END
C
C   OUTPUT PLOTTING FOR THE LEAST MEAN SQUARES SUBROUTINE
C
      SUBROUTINE PLT  (C,SCALE,TESTNO,NUMSEN,TIME,YY,VXR,BX,TTB,INDEX,
     1NOR,DIRC,NFRM)
      INTEGER C,TESTNO,NUMSEN,INDEX,NOR,NFRM
      REAL YY(INDEX),BX(NUMSEN),
     1VXR(INDEX),TTB(NUMSEN),TIME(1024),SCALE
      IF((C).EQ.(1)) CALL COMPRS
      IF((C).NE.(1)) CALL TEK618
      CALL PAGE(11.0,8.5)
      CALL NOBRDR
      CALL BLOWUP(SCALE)
      CALL AREA2D(9.0,6.0)
      CALL FRAME
      CALL XNAME('ANGLE-DEGREES-',14)
      CALL YNAME('RELATIVE DELAY TIMES',20)
      CALL HEADIN('LEAST MEAN SQUARES POLYNOMIAL',29,2.0,1)
      CALL MESSAG('EVENT NUMBER',12,.25,.65)
      CALL INTNO(TESTNO,2.5,.65)
      CALL MESSAG('DEGREE POLYNOMIAL',17,.25,.45)
      CALL INTNO(NOR,2.5,.45)
C
      IF((NFRM).EQ.(0))CALL MESSAG('INITIAL DIRECTION',17,.25,.25)
      IF((NFRM).EQ.(0))CALL REALNO(DIRC,2,2.4,.25)
      IF((NFRM).NE.(0))CALL MESSAG('TARGET TYPE',11,.25,.25)
      IF((NFRM).EQ.(1))CALL MESSAG('TRK VEH',7,2.5,.25)
      IF((NFRM).EQ.(2))CALL MESSAG('WHLD VEH',8,2.5,.25)
      IF((NFRM).EQ.(3))CALL MESSAG('SHL BLST',8,2.5,.25)
      IF((NFRM).EQ.(4))CALL MESSAG('HELO',4,2.5,.25)
      IF((NFRM).EQ.(5))CALL MESSAG('PERS',4,2.5,.25)
      CALL MESSAG('TIME PERIOD(SEC)',16,.25,.05)
      S = FLOAT(IFIX(TIME(1)))
      F = FLOAT(IFIX(TIME(1024) + 1.))
      CALL REALNO(S,2,2.4,.05)
      CALL REALNO(F,2,3.2,.05)
      CALL MESSAG('ACTUAL SENSOR DATA ARE INDICATED',32,2.5,5.7)
      CALL MESSAG('BY MARKER SYMBOLS',17,3.3,5.5)
      CALL INTAXS
```

```
      CALL YAXANG(0.)
      CALL XTICKS(10)
      CALL YTICKS(10)
      TS = VXR(1)
      TF = VXR(INDEX)
      CALL MAXMIN(YY,INDEX,K,YMAX,L,YMIN)
      IF((YMAX).LE.(YMIN)) YMAX = - YMAX
      CALL MAXMIN(TTB,NUMSEN,K,TMAX,L,TMIN)
      IF((TMAX).LE.(TMIN)) TMAX = - TMIN
      IF((TMAX).GT.(YMAX)) YMAX = TMAX
      IF((TMIN).LT.(YMIN)) YMIN = TMIN
      CALL GRAF(TS,'SCALE',TF,YMIN,'SCALE',YMAX)
      CALL RESET ('MARKER')
      CALL CURVE(VXR,YY,INDEX,0.)
      CALL MARKER(10)
      CALL CURVE (BX,TTB,NUMSEN,-1)
      CALL RESET ('MARKER')
      CALL ENDPL (0)
      RETURN
      END
C
C    MATRIX SOLVING ROUTINE
C
      SUBROUTINE SOLV(TRIX,NZ,B)
      DIMENSION TRIX(9,9),B(9),WKAREA(108)
      CALL LEQT2F (TRIX,1,NZ,9,B,0,WKAREA,IER)
      RETURN
      END
```

LIST OF REFERENCES

1. Naval Ocean Systems Command Technical Report 747, Seismic/Acoustic Field Measurements and Analysis, by R. G. Hock, J. G. Hoffman, A. T. Roome, L. H. Bossert and J. H. Brown, 9 November 1981.

2. Grant, F. S., Interpretation Theory in Applied Geophysics, pp.5 - 11, McGraw Hill, 1965.

3. Orincon Corporation, Signal Processing for Seismic Surveillance, by H. W. Sorenson, pp.1 - 35, July 1981.

4. Shelef, S. C., Phase Difference/Time Delay Trace Functions and their Application to Bearing Estimation in Arrays, Ph.d. Thesis, Naval Postgraduate School, 1979.

5. Dublin, C. P., Marine Corps Passive Surveillance Requirements, Masters Thesis, Naval Postgraduate School, Monterey, 1980.

6. Skolnik, M. I., Introduction to Radar Systems. pp. 373 - 376, 428 - 431, McGraw-Hill, 1980.

7. Cooper, G. R., and Mc Gillem C. D., Probabilistic Methods of Signal and System Analysis, pp 205 - 210, Holt, Rinehart, and Winston, 1971.

8. Oppenheim, A. V., and Schafer, R. W., Digital Signal Processing, pp. 111 - 115, Prentice - Hall, 1975.

9. Park, S., Detection, Classification and Locating via Seismic/Acoustic Sensors, Masters Thesis, Naval Postgraduate School, Monterey, 1982.

10. Gerald, C. F., Applied Numerical Analysis, pp.465 - 474, Addision-Wesley, 1980.

11. Salvadori, M. G., and Baron, M. L., Numerical Methods in Engineering, pp.65 - 87, Prentice-Hall, 1961.

12. Naval Postgraduate School Technical Note MVS - 01, Users Guide to MVS at NPS, by June Favorite, pp.1 - 154, July 1983.

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